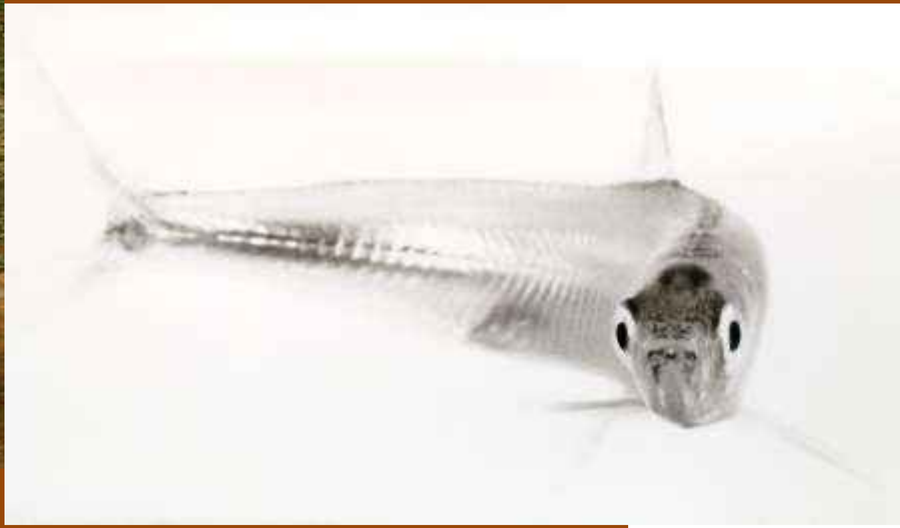
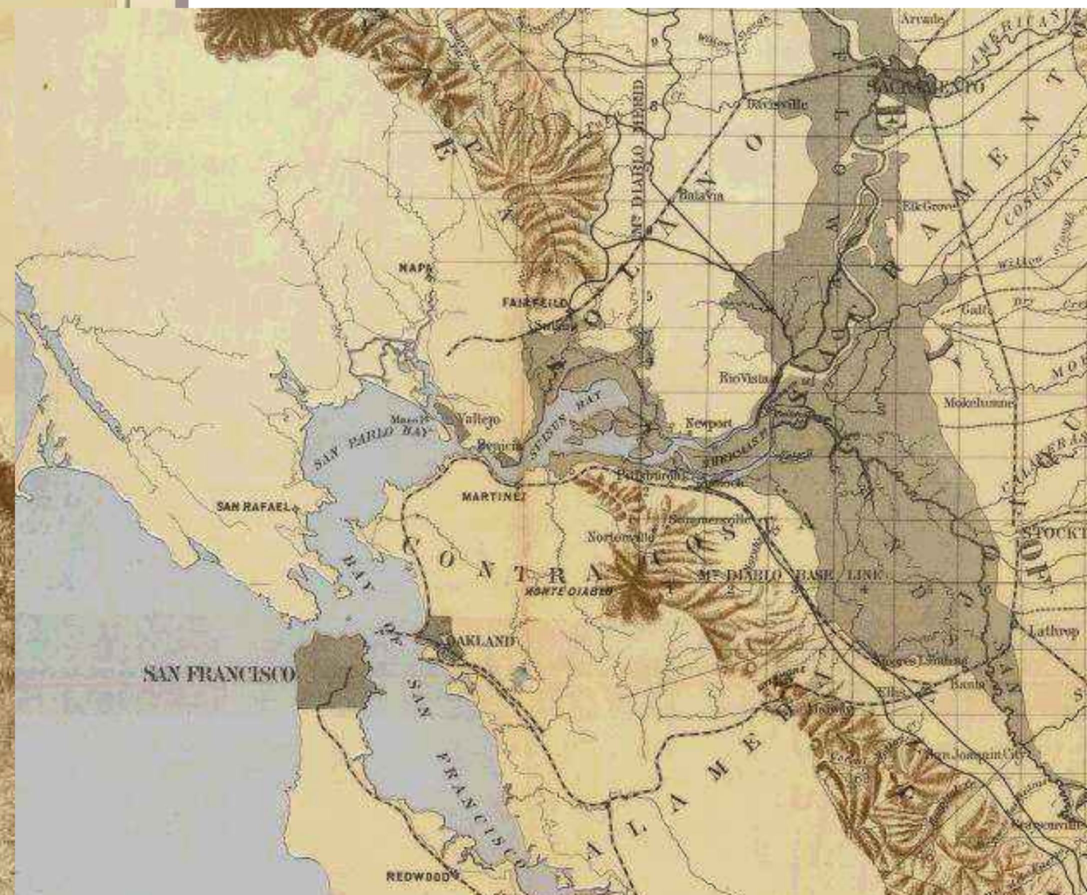
Value of Wetlands to Fish



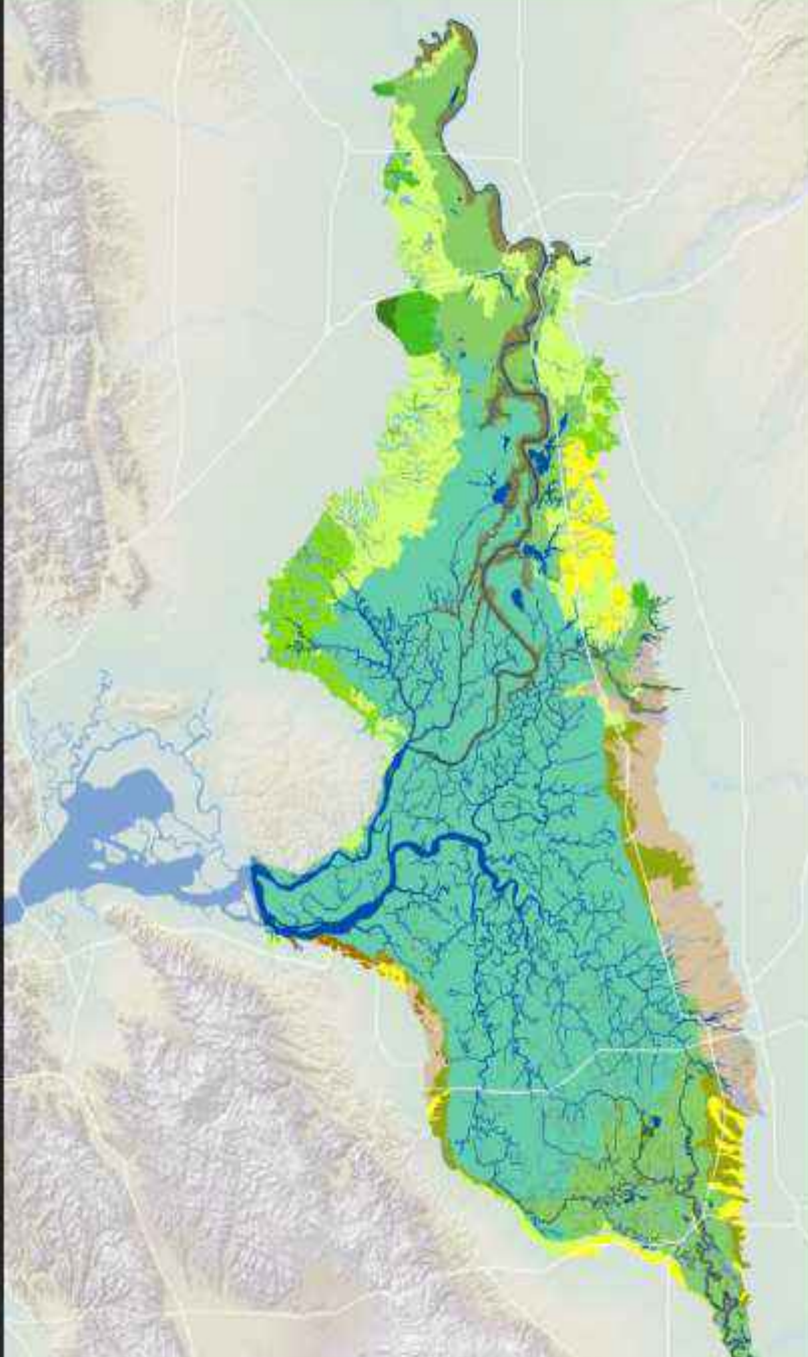
Bruce Herbold,
Estuarine Ecology Consultant,

Wim Kimmerer, Romberg Tiburon Center,
San Francisco State University

MAP
SAN JOAQUIN, SACRAMENTO
TULARE VALLEYS
STATE OF CALIFORNIA



SACRAMENTO
Arcade
Davisville
Batavia
Elk Grove
NAPA
FAIRFIELD
Suisun
Galt
Rio Vista
Mokelumne
Newport
Vallejo
Benicia
SAN PABLO BAY
SUISUN BAY
MARTINEZ
SAN RAFAEL
Pittsburg
Somersville
Nortonville
MONTE DIABLO
MT DIABLO BASE LINE
MT DIABLO MERID.
CONTRA COSTA
OAKLAND
SAN FRANCISCO
BAY OF SAN FRANCISCO
ALAMEDA
Lathrop
San Joaquin City
REDWOOD

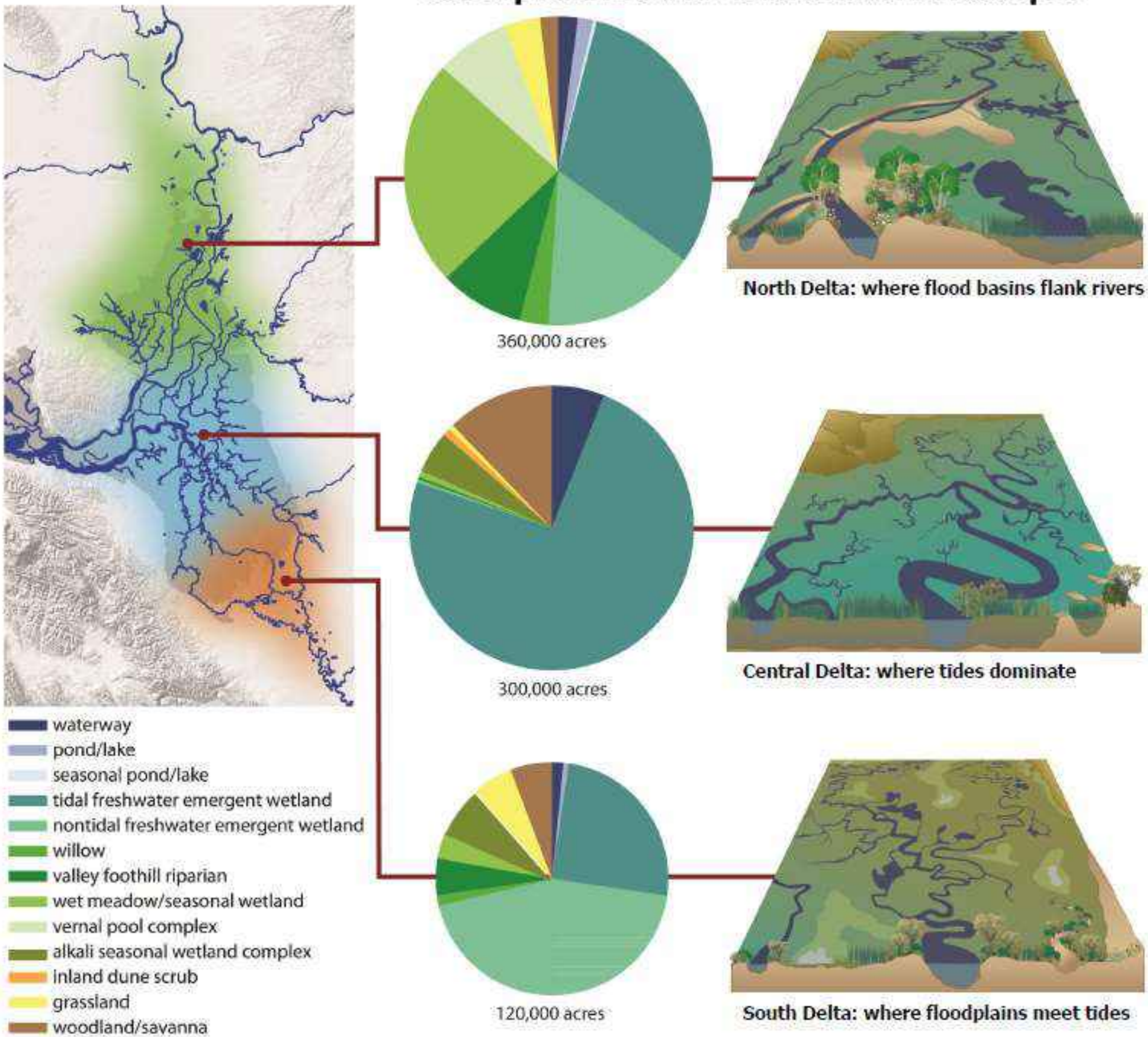


Salmon Slough: "The stream bed is **full of logs** and the boats grounded two or three times." (Abella 1811)

"The **small fish run into the sloughs and lakes** as soon as the water gets sufficiently high, and **return to the river when it begins to get low**." (Sacramento Daily Union, 6 June 1854)

Tule marsh water was "so thoroughly impregnated with decaying vegetable matter that **it looked more like sherry than water**..." (Wright ca. 1850)

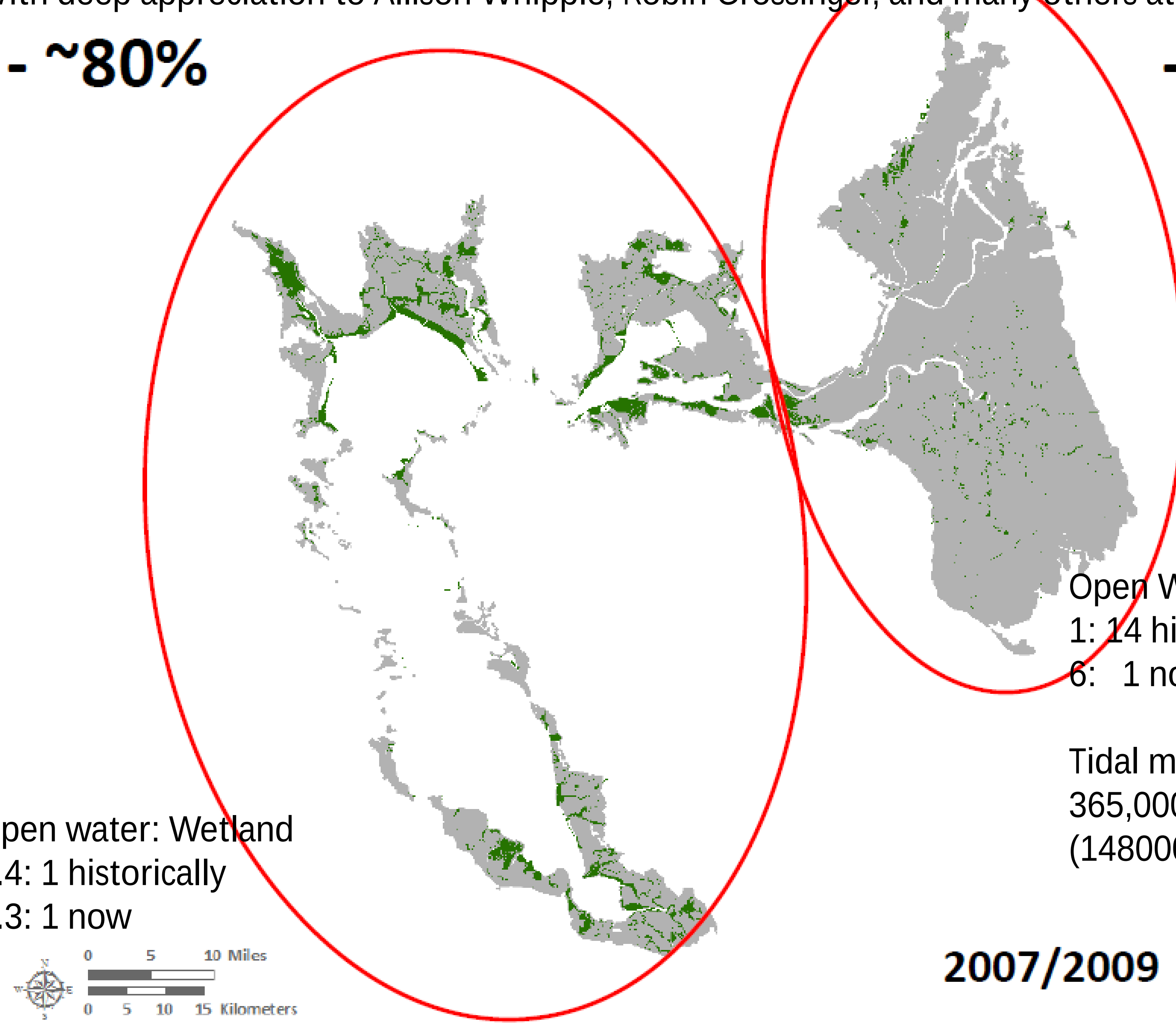
Conceptual models of historical landscapes



With deep appreciation to Allison Whipple, Robin Grossinger, and many others at SFEI

- ~80%

- ~97%*



Open Water:Wetland
1: 14 historically
6: 1 now

Tidal marsh:
365,000 acres
(148000 ha)

Open water: Wetland
1.4: 1 historically
6.3: 1 now

2007/2009


Major Rivers
State Projects
Federal Projects
Local Projects
All Water Projects
Redding
Sacramento
San Francisco
Fresno
Los Angeles
San Diego


Sacramento
Freeport
Hood
DELTA AREA
YOLO BYPASS
NORTH BAY AQUEDUCT
DELTA CROSS CHANNEL
Walnut Grove
COSUMNES RIVER
MOKELUMNE RIVER
Rio Vista
Lodi
SUISUN MARSH SALINITY CONTROL GATE
Chipps Island
Threemile Slough
SACRAMENTO RIVER
Columbia Cut
SAN JOAQUIN
Pittsburg
Antioch
CONTRA COSTA CANAL
Sherman Lake
Jersey Point
Dutch Slough
OLD RIVER
Turner Cut
Stockton
Bacon Island
MIDDLE RIVER
Victoria Canal
EXPLANATION
Existing stations
Proposed
Clifton Court Forebay
GRANTLINE CANAL
State Water Project pumping plant
Central Valley Project pumping plant
OLD RIVER
Tracy
CALIFORNIA AQUEDUCT
DELTA-MENDOTA CANAL
0 4 8 12 MILES
0 4 8 12 KILOMETERS

USGS

IEP Tidal Wetlands Monitoring Project Work Team DRAFT Conceptual Models

- Developed principally by: Adam Ballard, Jenny Bigman, Larry Brown, Louise Conrad, Dave Contreras, Steve Culberson, Chris Enright, Pascale Goetler, Rosemary Hartman, Bruce Herbold, Jim Hobbs, Joseph Kirsh, Alice Low, Anitra Pawley, Ted Sommer, Hildie Spautz, Stacy Sherman, Jan Thompson, and Dave Zezulak.
- With liberal borrowing from:
  - DRERIP models (https://www.dfg.ca.gov/erp/conceptual_models.asp)
  - the MAST draft report (Baxter et al 2013), and the
  - Suisun Marsh conceptual models draft (Siegel et al, 2010).

Tidal Wetland model

Developed by Rosemary Hartman, Stacy Sherman, Dave Contreras, Alice Low, and Bruce Herbold, based on the DRERIP tidal marsh model, Kneib et al 2008

Tier 1: Landscape Attributes

Land use
Diversions
Outfalls

Seasonality

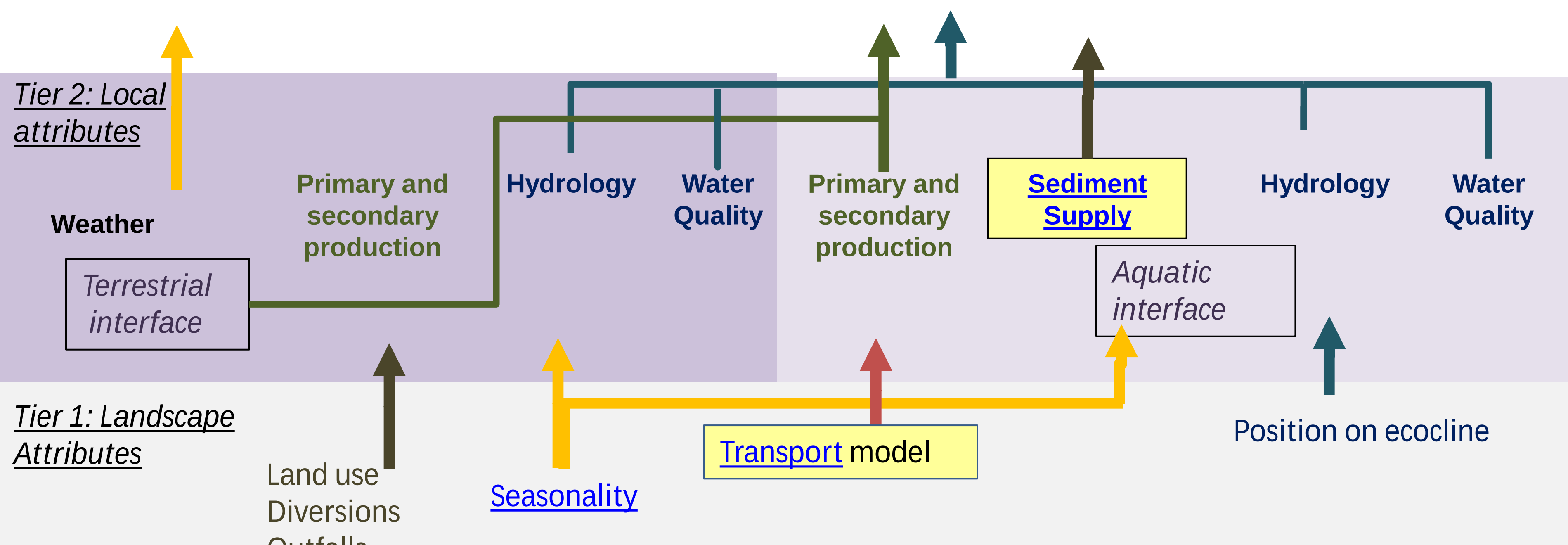
Transport model

Position on ecocline

- Proximity to ocean
- Distance from midchannel

Tidal Wetland model

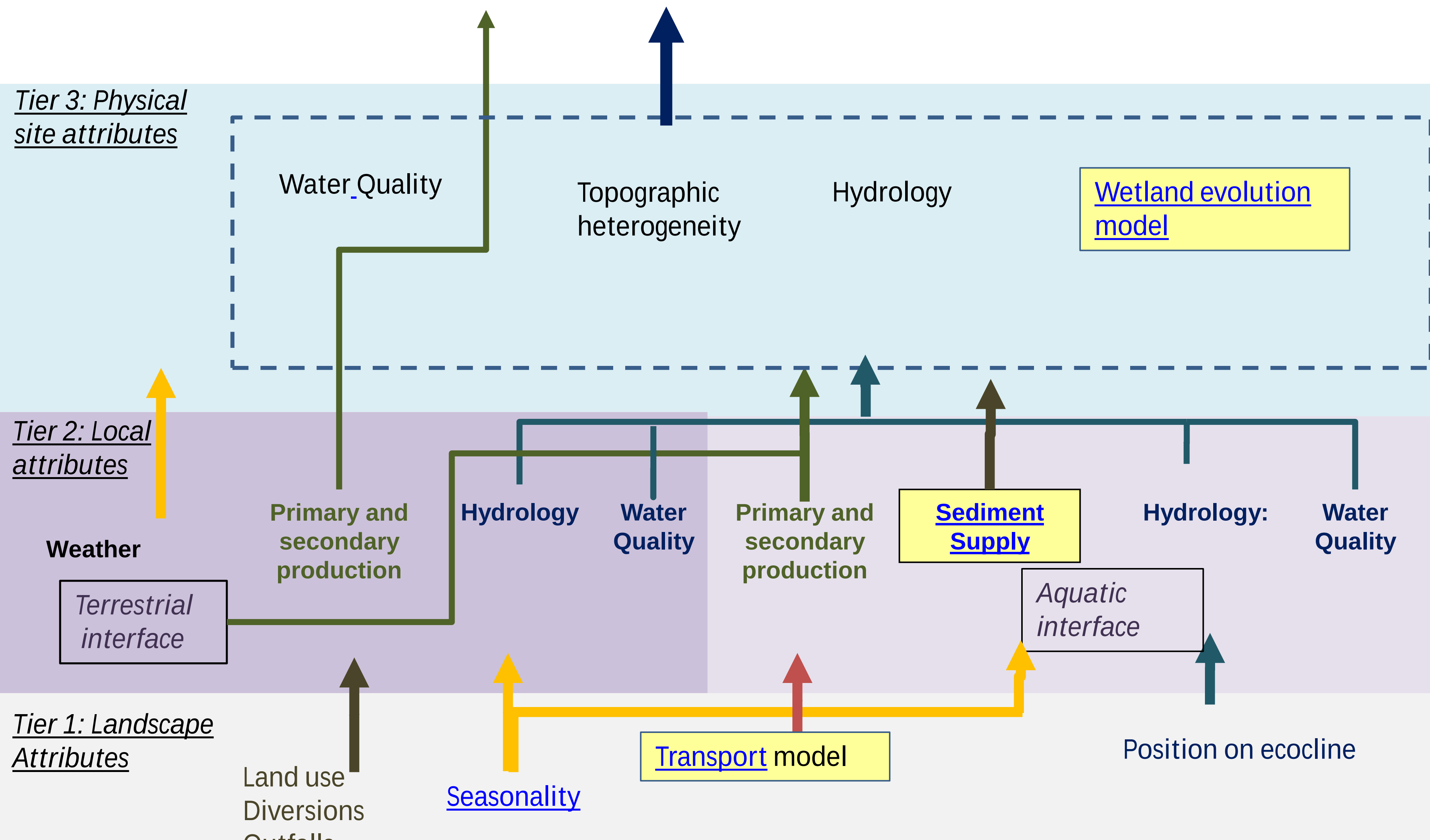
Developed by Rosemary Hartman, Stacy Sherman, Dave Contreras, Alice Low, and Bruce Herbold, based on the DRERIP tidal marsh model, Kneib et al 2008



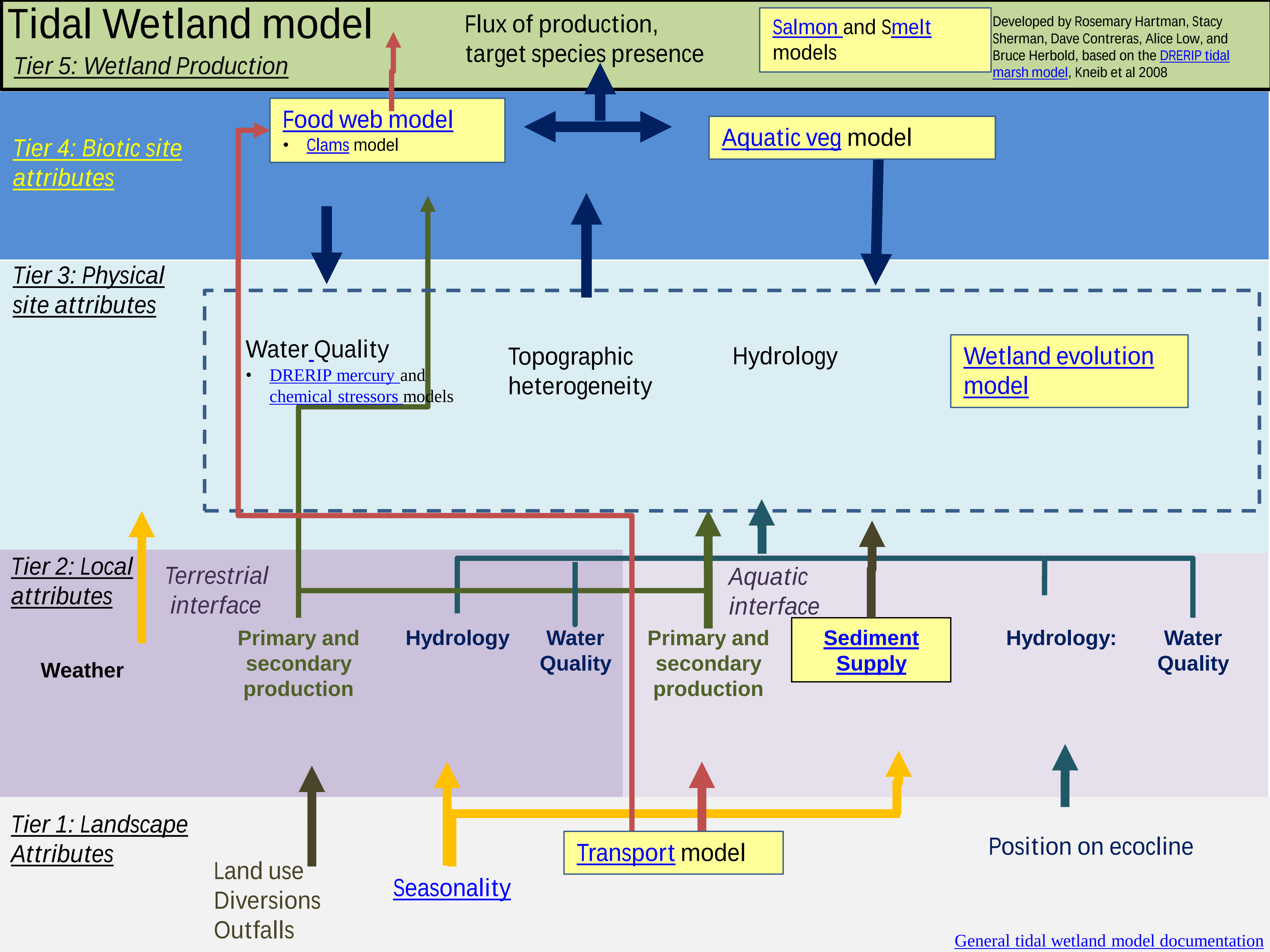
General tidal wetland model documentation

Tidal Wetland model

Developed by Rosemary Hartman, Stacy Sherman, Dave Contreras, Alice Low, and Bruce Herbold, based on the [DRERIP tidal marsh model], Kneib et al 2008

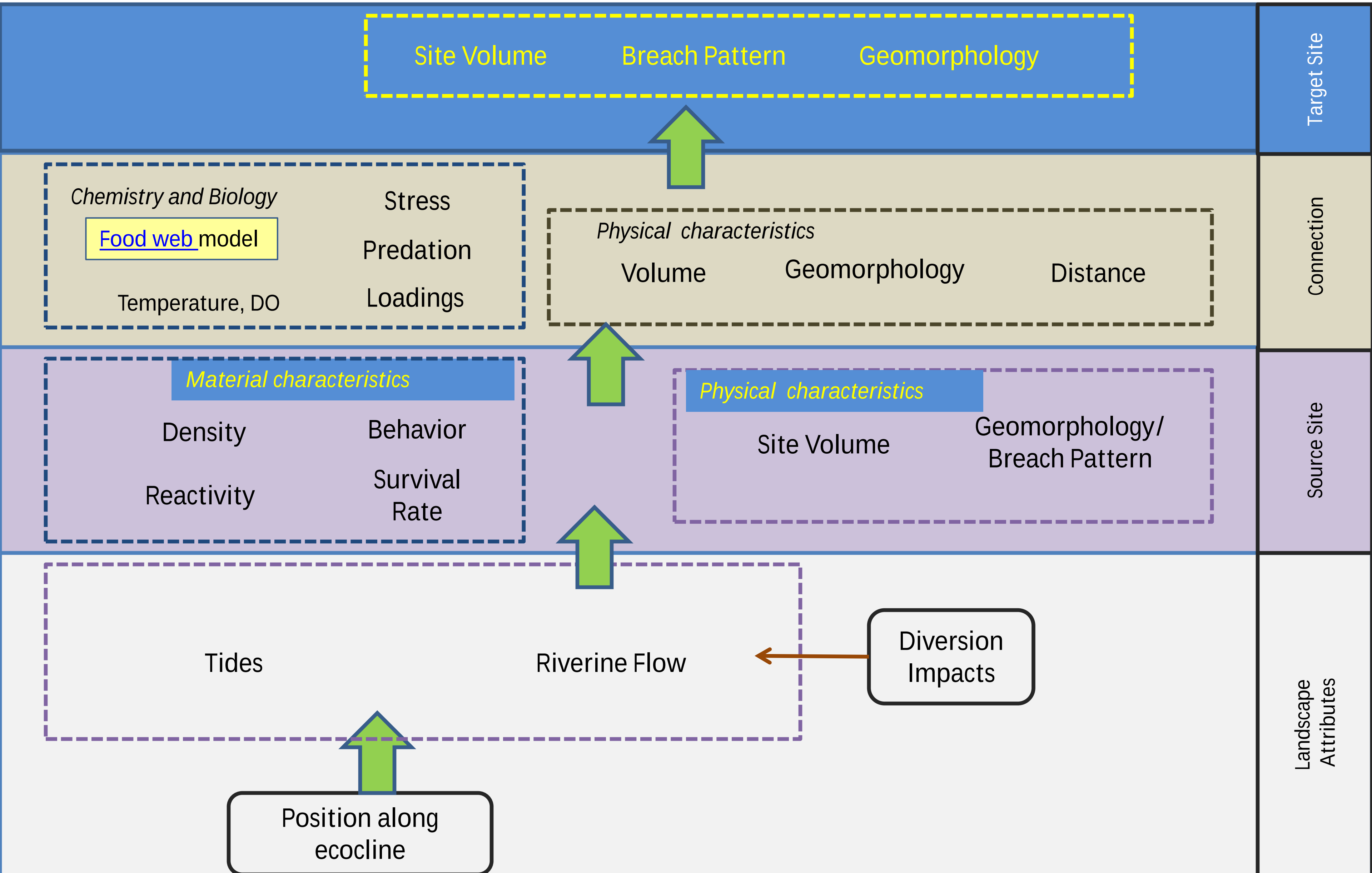


General tidal wetland model documentation


Tidal Wetland model
Tier 5: Wetland Production
Flux of production, target species presence
Salmon and Smelt models
Developed by Rosemary Hartman, Stacy Sherman, Dave Contreras, Alice Low, and Bruce Herbold, based on the DRERIP tidal marsh model, Kneib et al 2008
Tier 4: Biotic site attributes
Food web model
• Clams model
Aquatic veg model
Tier 3: Physical site attributes
Water Quality
• DRERIP mercury and chemical stressors models
Topographic heterogeneity
Hydrology
Wetland evolution model
Tier 2: Local attributes
Terrestrial interface
Weather
Primary and secondary production
Hydrology
Water Quality
Aquatic interface
Primary and secondary production
Sediment Supply
Hydrology:
Water Quality
Tier 1: Landscape Attributes
Land use
Diversions
Outfalls
Seasonality
Transport model
Position on ecocline
General tidal wetland model documentation

Transport model

Exchange of Specified Material between Source and Target sites



Seasonal Wetland Change model

Transport model

Tier 1 - Landscape Attributes

Proximity to ocean, water diversion sites, contaminant sources, and other wetlands

Tier 2 – Regional inputs/drivers

Weather, River Flows, Turbidity, Contaminant and Nutrient Loading

Tier 3 – Wetland physical processes

Wetland evolution model

Sediment accretion and erosion, Mobilization of materials, Connection to surrounding water and terrestrial environments

Tier 4 – Wetland biotic processes

Greater flux of organisms and detritus across aquatic interface

Tier 5 – Wetland Production

Smelt and smolt presence

Food web model

Plant growth, phytoplankton production

Higher metabolic and growth rates, Clam grazing

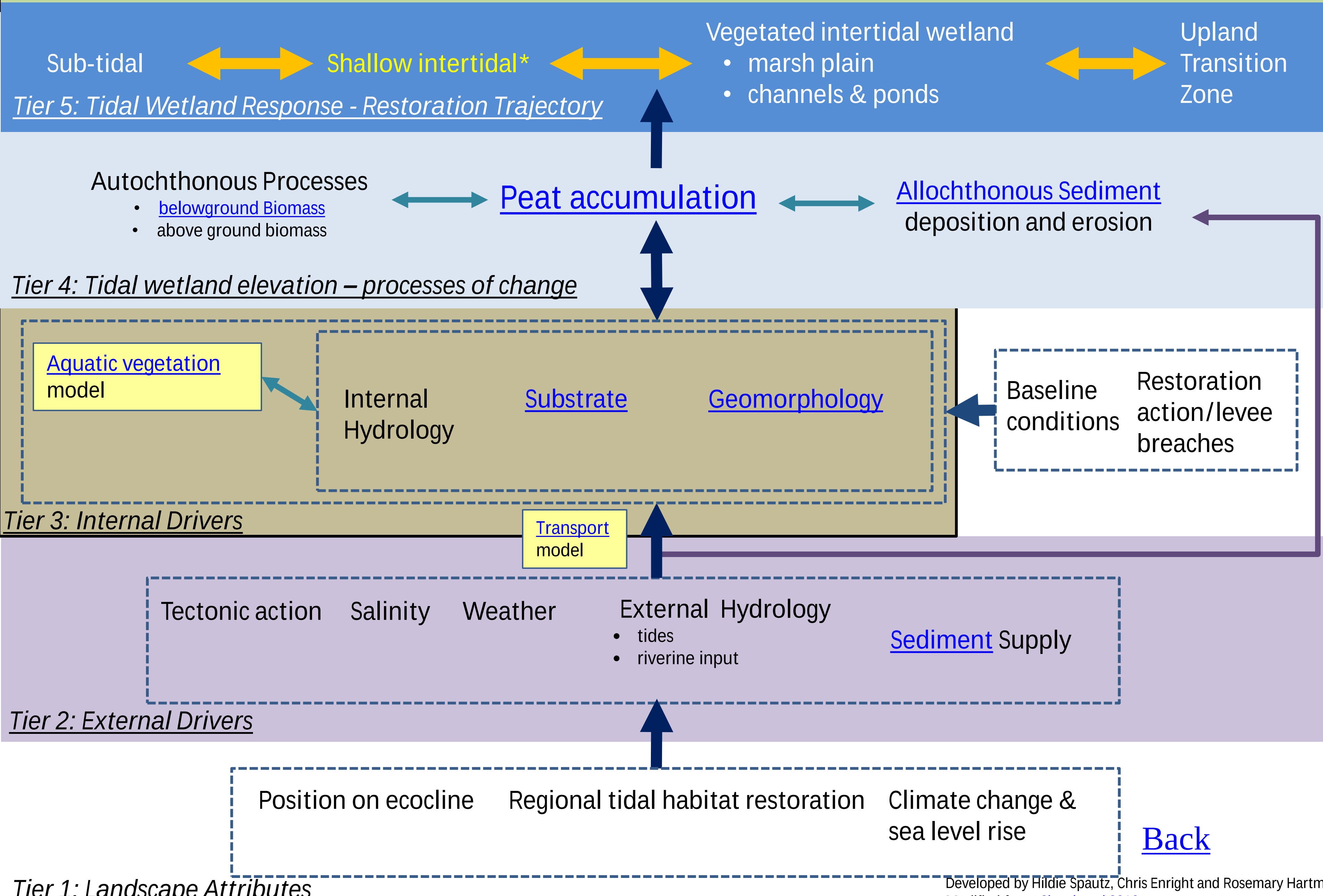
WINTER/ SPRING: Connective season

SUMMER/ FALL: *In situ* season

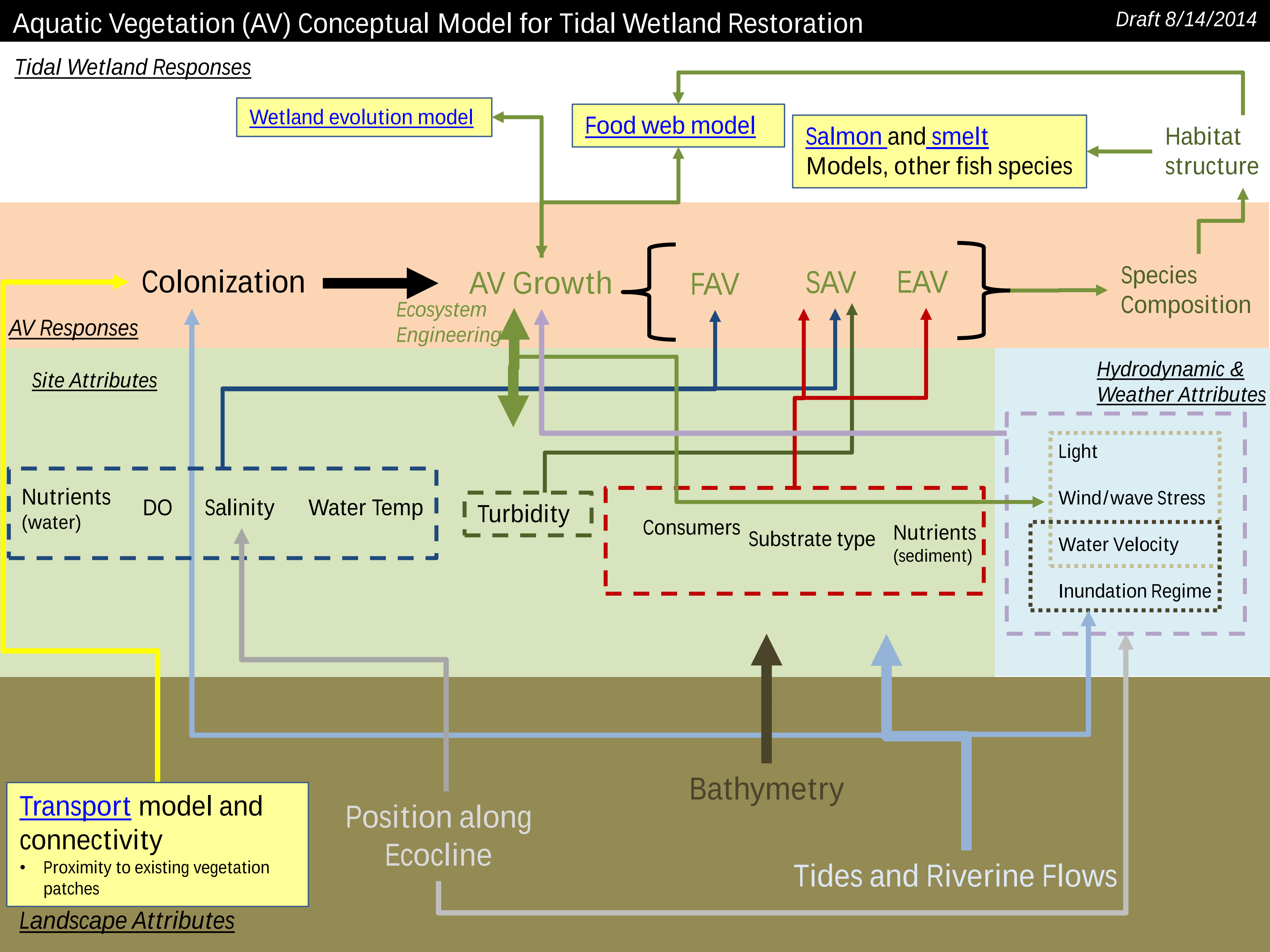
Longer Residence Time, lower DO, higher salinity, soil compaction/desiccation

Wind, Turbidity, Contaminants

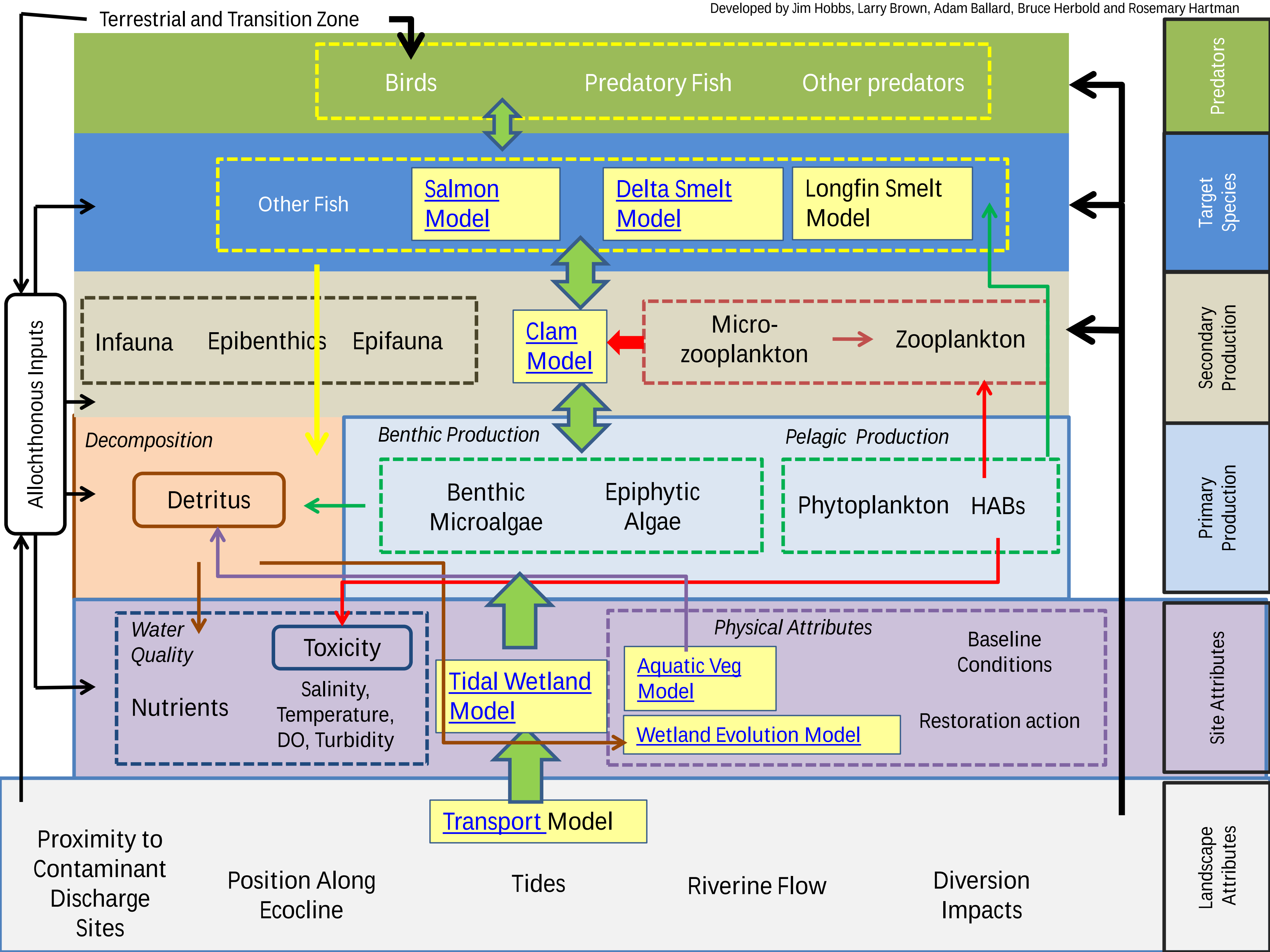
Tidal Wetland Restoration Evolution model



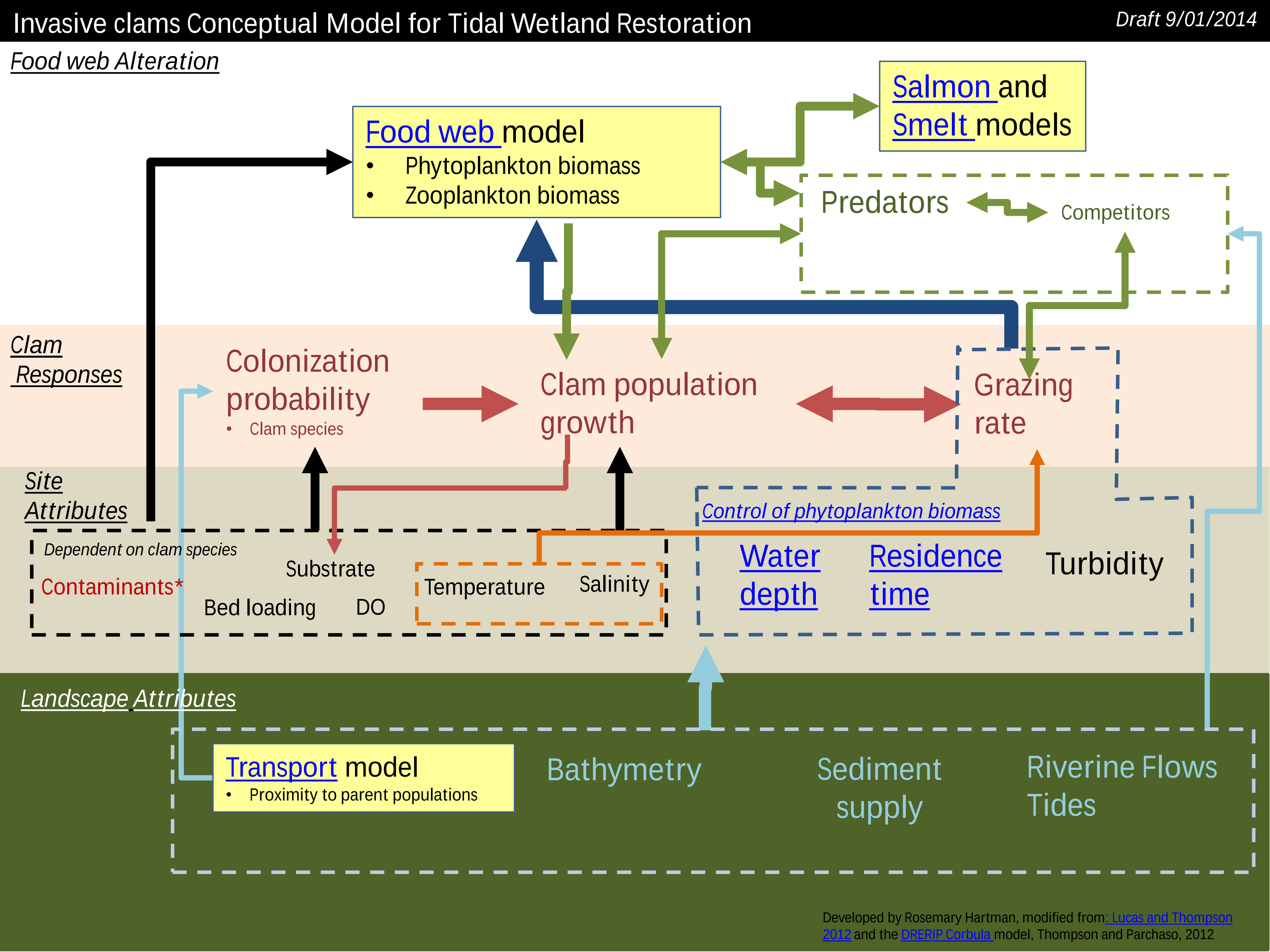
Developed by Hildie Spautz, Chris Enright and Rosemary Hartma
Modified from: Siegel et al 2010



Aquatic Vegetation (AV) Conceptual Model for Tidal Wetland Restoration
Draft 8/14/2014
Tidal Wetland Responses
Wetland evolution model
Food web model
Salmon and smelt Models, other fish species
Habitat structure
Colonization
AV Growth
Ecosystem Engineering
FAV
SAV
EAV
Species Composition
AV Responses
Site Attributes
Hydrodynamic & Weather Attributes
Light
Wind/wave Stress
Water Velocity
Inundation Regime
Nutrients (water)
DO
Salinity
Water Temp
Turbidity
Consumers
Substrate type
Nutrients (sediment)
Transport model and connectivity
• Proximity to existing vegetation patches
Position along Ecocline
Bathymetry
Tides and Riverine Flows
Landscape Attributes



Developed by Jim Hobbs, Larry Brown, Adam Ballard, Bruce Herbold and Rosemary Hartman
Terrestrial and Transition Zone
Birds
Predatory Fish
Other predators
Predators
Other Fish
Salmon Model
Delta Smelt Model
Longfin Smelt Model
Target Species
Allochthonous Inputs
Infauna
Epibenthics
Epifauna
Clam Model
Micro-zooplankton
Zooplankton
Secondary Production
Decomposition
Benthic Production
Pelagic Production
Detritus
Benthic Microalgae
Epiphytic Algae
Phytoplankton
HABs
Primary Production
Water Quality
Toxicity
Nutrients
Salinity, Temperature, DO, Turbidity
Tidal Wetland Model
Physical Attributes
Aquatic Veg Model
Baseline Conditions
Wetland Evolution Model
Restoration action
Site Attributes
Transport Model
Proximity to Contaminant Discharge Sites
Position Along Ecocline
Tides
Riverine Flow
Diversion Impacts
Landscape Attributes

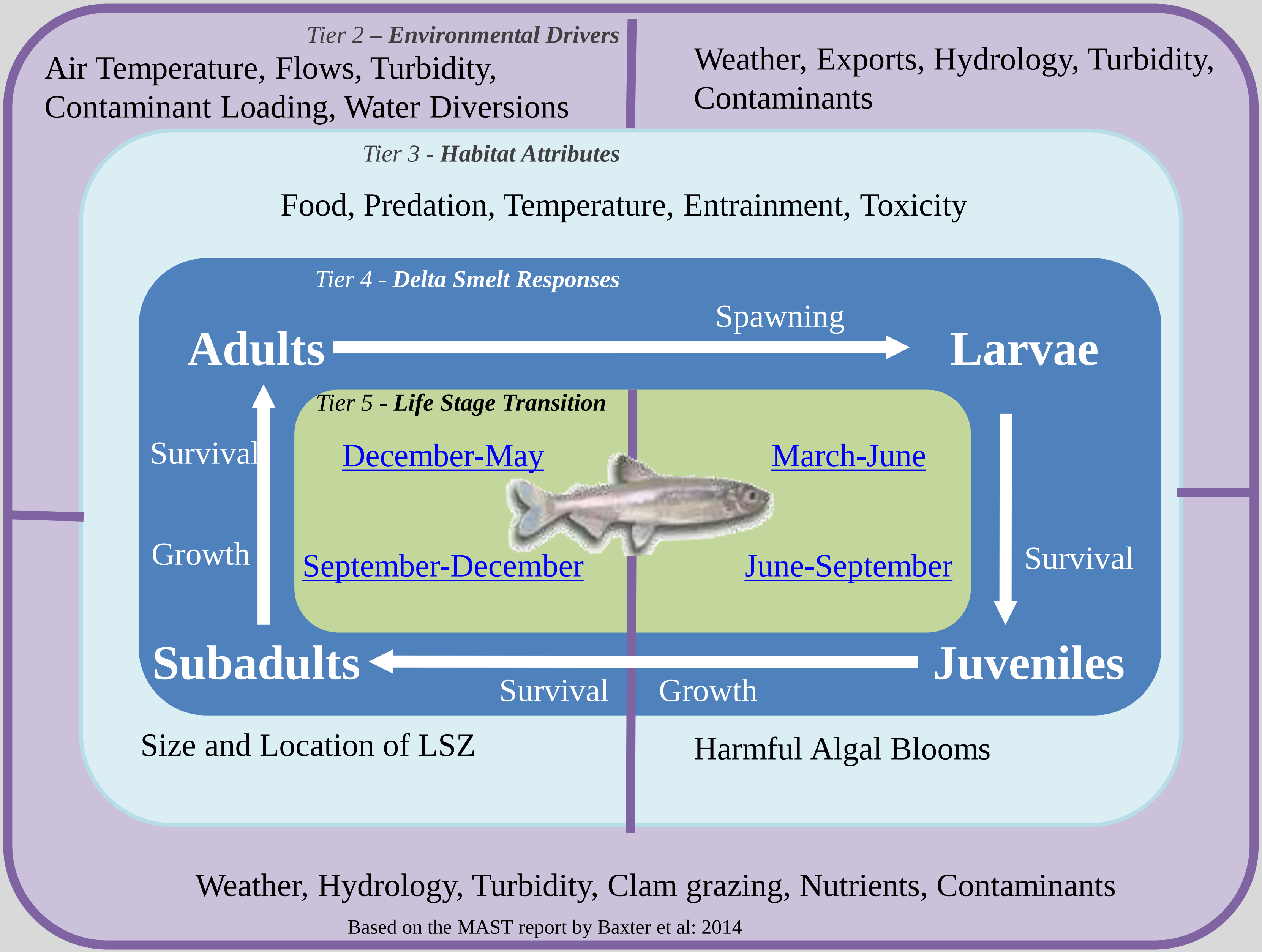


Invasive clams Conceptual Model for Tidal Wetland Restoration
Draft 9/01/2014
Food web Alteration
Food web model
• Phytoplankton biomass
• Zooplankton biomass
Salmon and Smelt models
Predators
Competitors
Clam Responses
Colonization probability
• Clam species
Clam population growth
Grazing rate
Site Attributes
Dependent on clam species
Contaminants*
Substrate
Bed loading
DO
Temperature
Salinity
Control of phytoplankton biomass
Water depth
Residence time
Turbidity
Landscape Attributes
Transport model
• Proximity to parent populations
Bathymetry
Sediment supply
Riverine Flows
Tides
Developed by Rosemary Hartman, modified from: Lucas and Thompson 2012 and the DRERIP Corbula model, Thompson and Parchaso, 2012

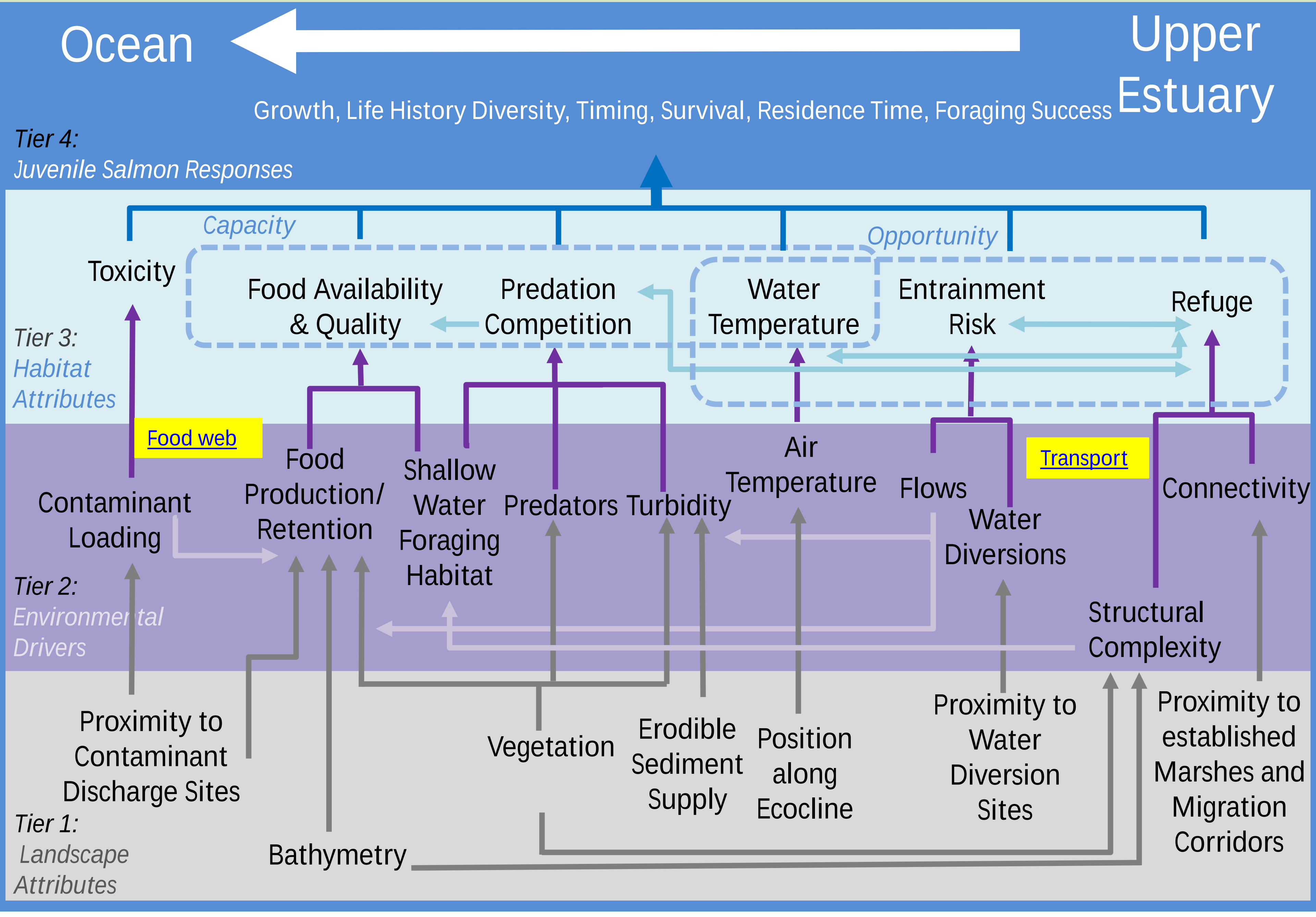
Delta smelt model

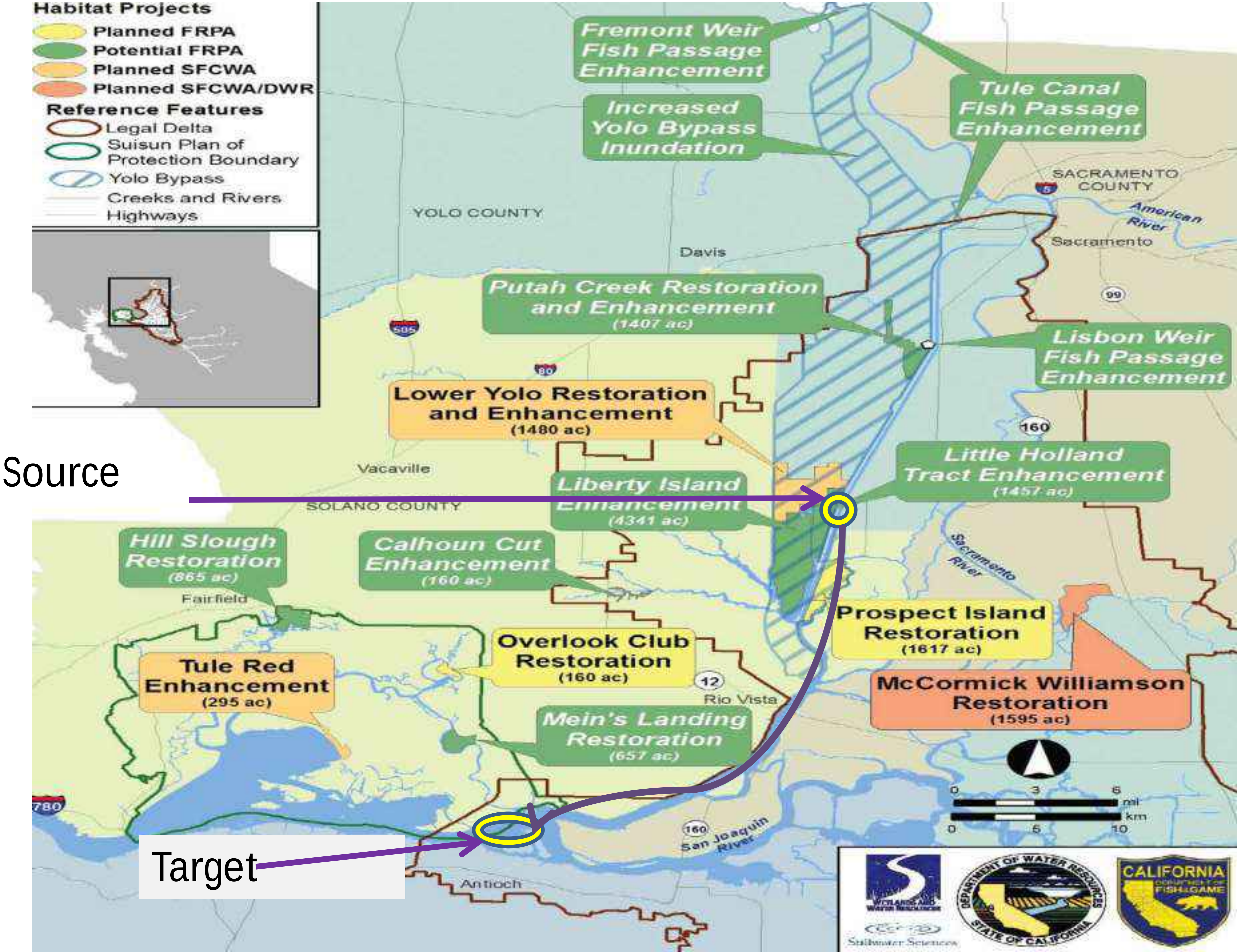
Tier 1 - ***Landscape Attributes***

Erodible Sediment Supply, Proximity to Ocean, Discharges & Diversions,
Bathymetry (Proximity to and Extent of Shallow Areas)

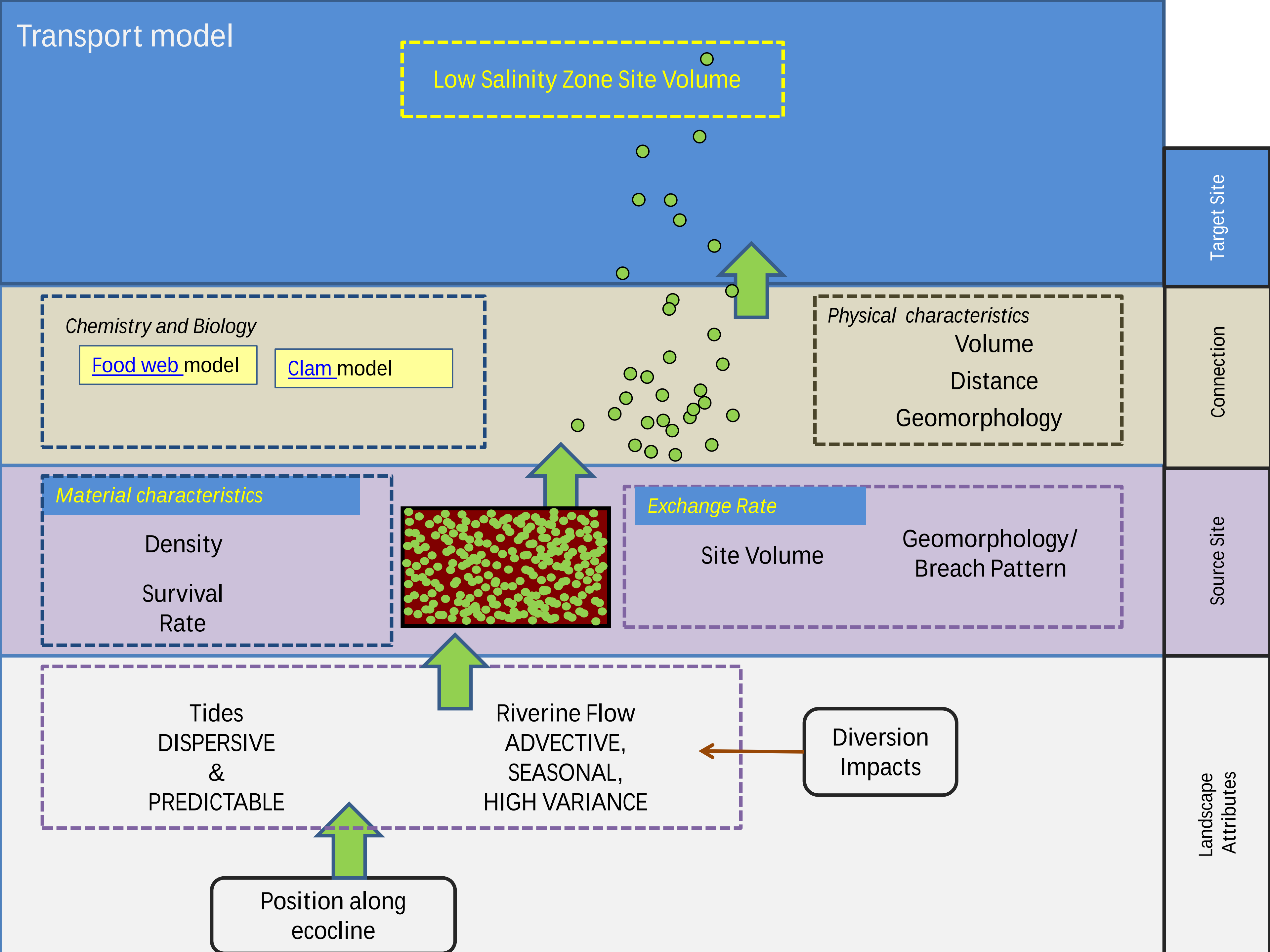


Chinook Salmon Tidal Wetland Model

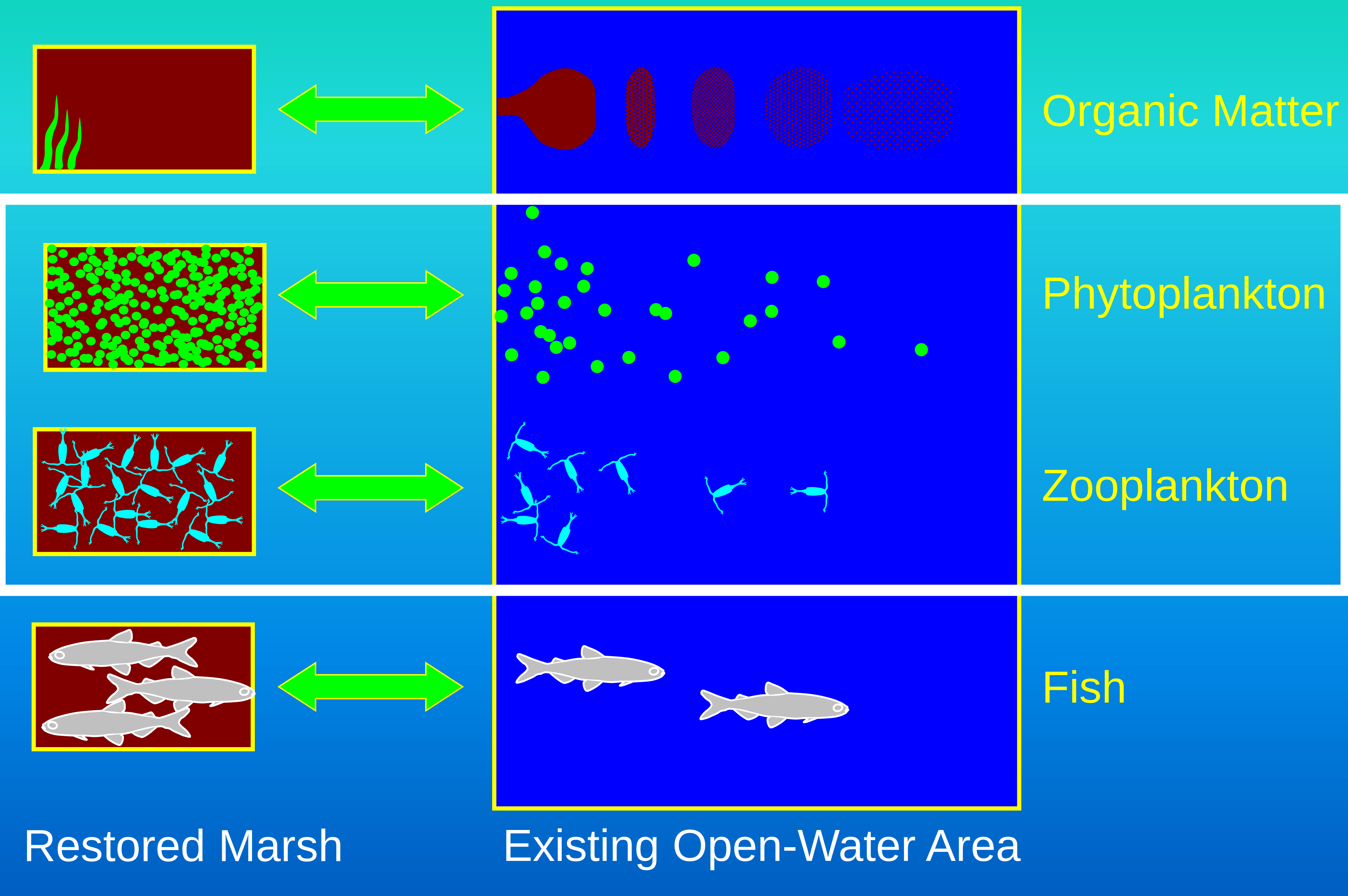




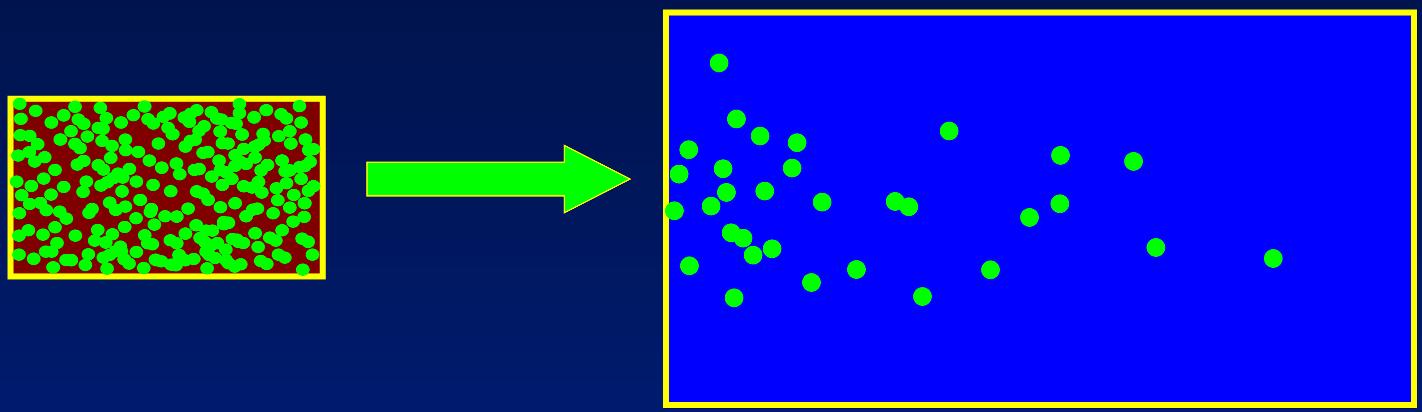
Habitat Projects
Planned FRPA
Potential FRPA
Planned SFCWA
Planned SFCWA/DWR
Reference Features
Legal Delta
Suisun Plan of Protection Boundary
Yolo Bypass
Creeks and Rivers
Highways
Fremont Weir Fish Passage Enhancement
Tule Canal Fish Passage Enhancement
Increased Yolo Bypass Inundation
SACRAMENTO COUNTY
American River
Sacramento
YOLO COUNTY
Davis
Putah Creek Restoration and Enhancement (1407 ac)
Lisbon Weir Fish Passage Enhancement
Lower Yolo Restoration and Enhancement (1480 ac)
Little Holland Tract Enhancement (1457 ac)
Vacaville
Source
SOLANO COUNTY
Liberty Island Enhancement (4341 ac)
Sacramento River
Hill Slough Restoration (865 ac)
Calhoun Cut Enhancement (160 ac)
Fairfield
Prospect Island Restoration (1617 ac)
Overlook Club Restoration (160 ac)
Tule Red Enhancement (295 ac)
Rio Vista
McCormick Williamson Restoration (1595 ac)
Mein's Landing Restoration (657 ac)
0 3 6 mi
0 5 10 km
San Joaquin River
Target
Antioch
CALIFORNIA DEPARTMENT OF FISH & GAME
DEPARTMENT OF WATER RESOURCES STATE OF CALIFORNIA
Stillwater Sciences

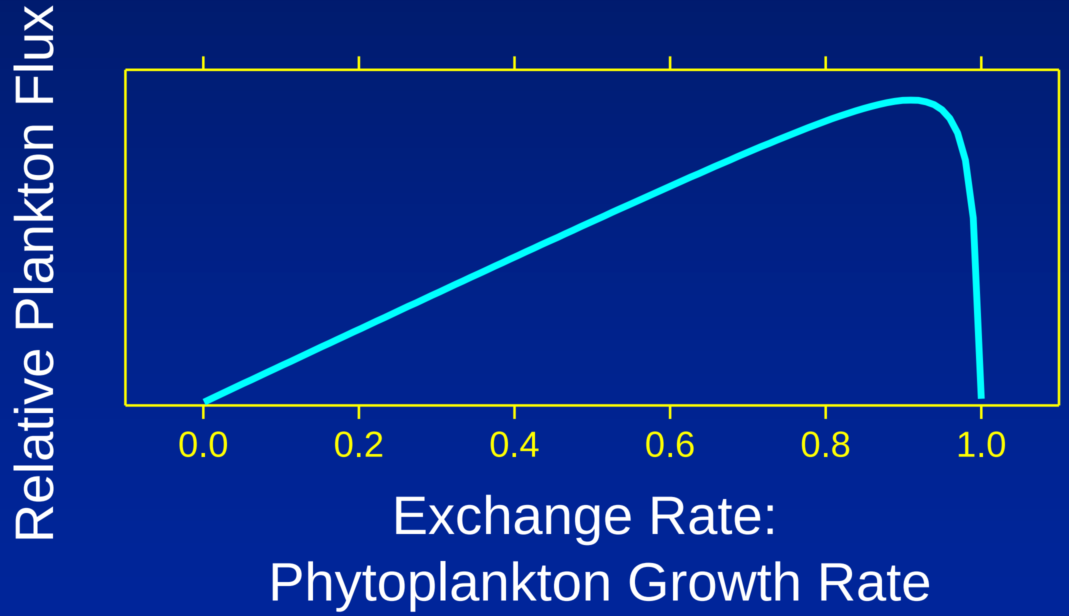

Transport model
Low Salinity Zone Site Volume
Target Site
Chemistry and Biology
Food web model
Clam model
Physical characteristics
Volume
Distance
Geomorphology
Connection
Material characteristics
Density
Survival
Rate
Exchange Rate
Site Volume
Geomorphology/
Breach Pattern
Source Site
Tides
DISPERSIVE
&
PREDICTABLE
Riverine Flow
ADVECTIVE,
SEASONAL,
HIGH VARIANCE
Diversion
Impacts
Position along
ecocline
Landscape
Attributes

Subsidies from wetland



Subsidies from marsh vary with exchange





Model

Steady state

Single limiting nutrient

Saturating uptake

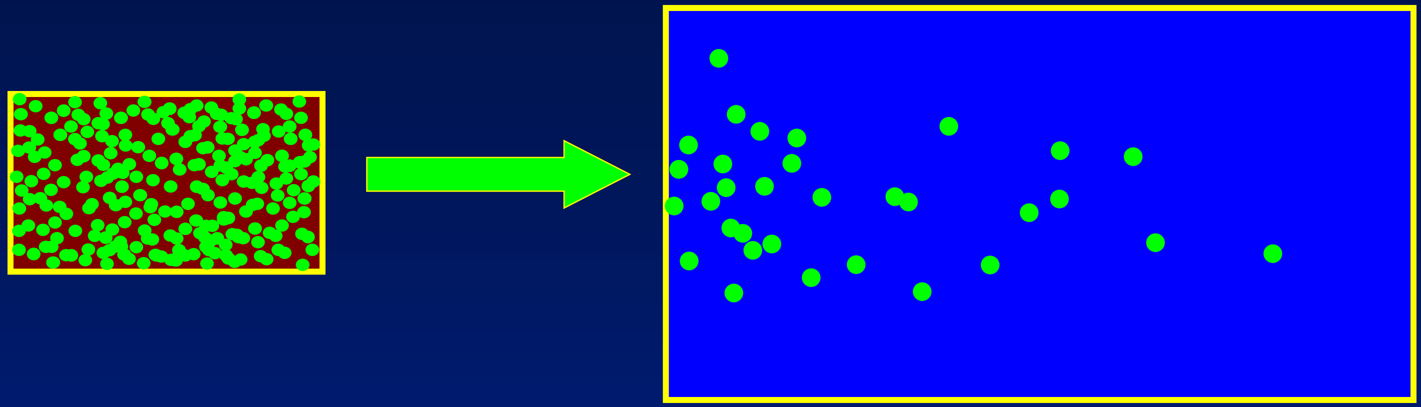
No grazing

Negligible phytoplankton conc. in estuary

Exchange rate = Daily exchange volume / marsh volume

= 1 / Residence time of marsh

Subsidies from wetland: phyto model

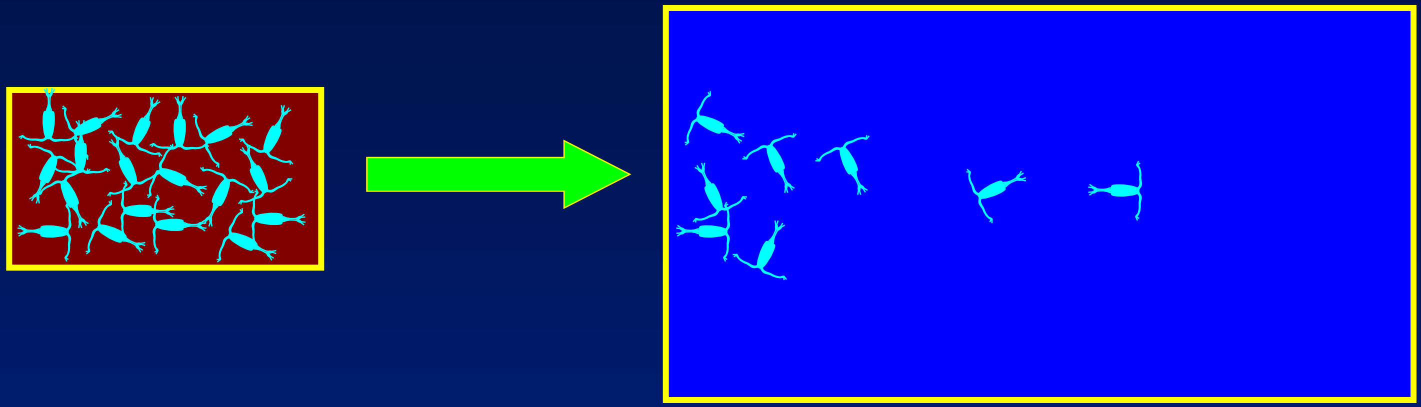


Area	1000 ha	Volume	0.5 km^3
Depth	2m	Phytoplankton	73 mgC m^{-3}
Phytoplankton	900 mgC m^{-3}		
Growth rate μ	0.86 d^{-1}		
Microzoo grazing	60% μ		
Residence time	10d		

Resulting subsidy:

5% of existing phytoplankton biomass d^{-1}

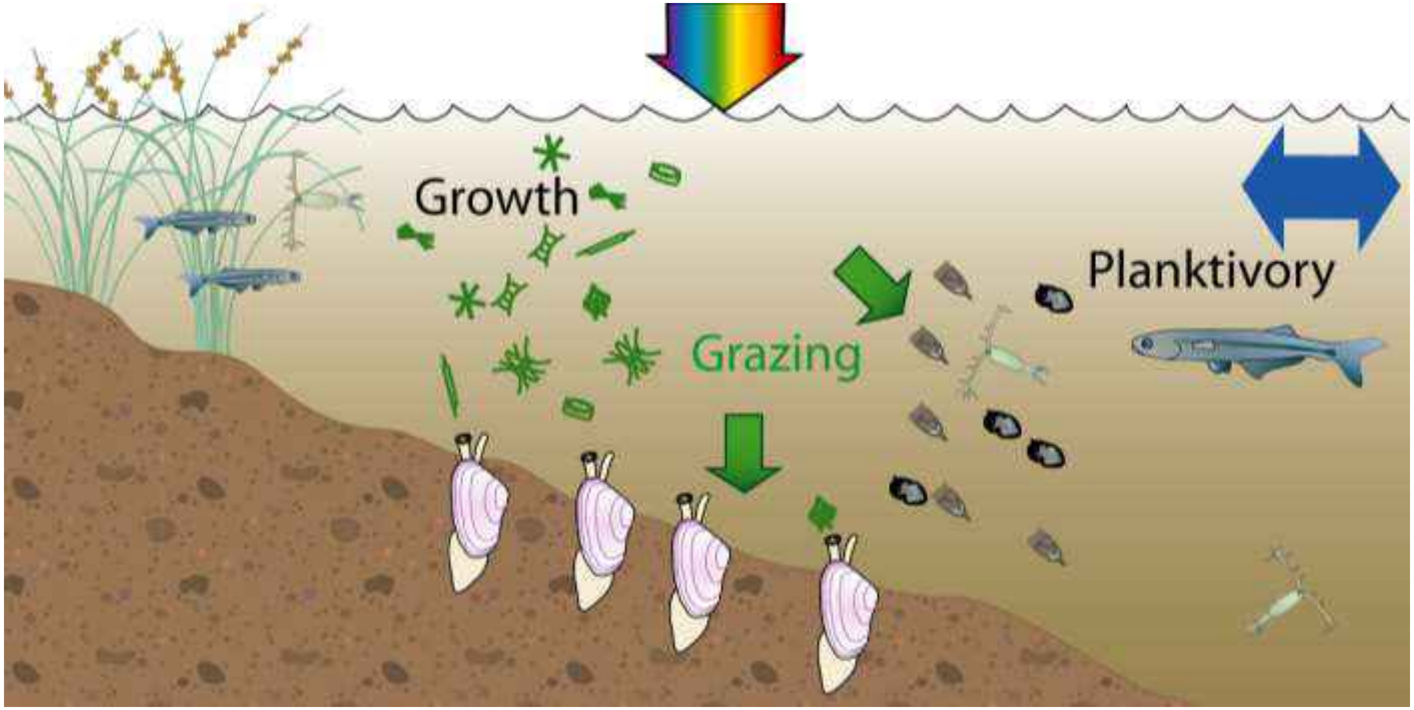
Subsidies from wetland: copepod model



Area	1000 ha	Volume	0.5 km^3
Depth	2m	Copepods	3 mgC m^{-3}
Copepods	23 mgC m^{-3}		
Growth rate μ	0.1 d^{-1}		
Residence time	10d		

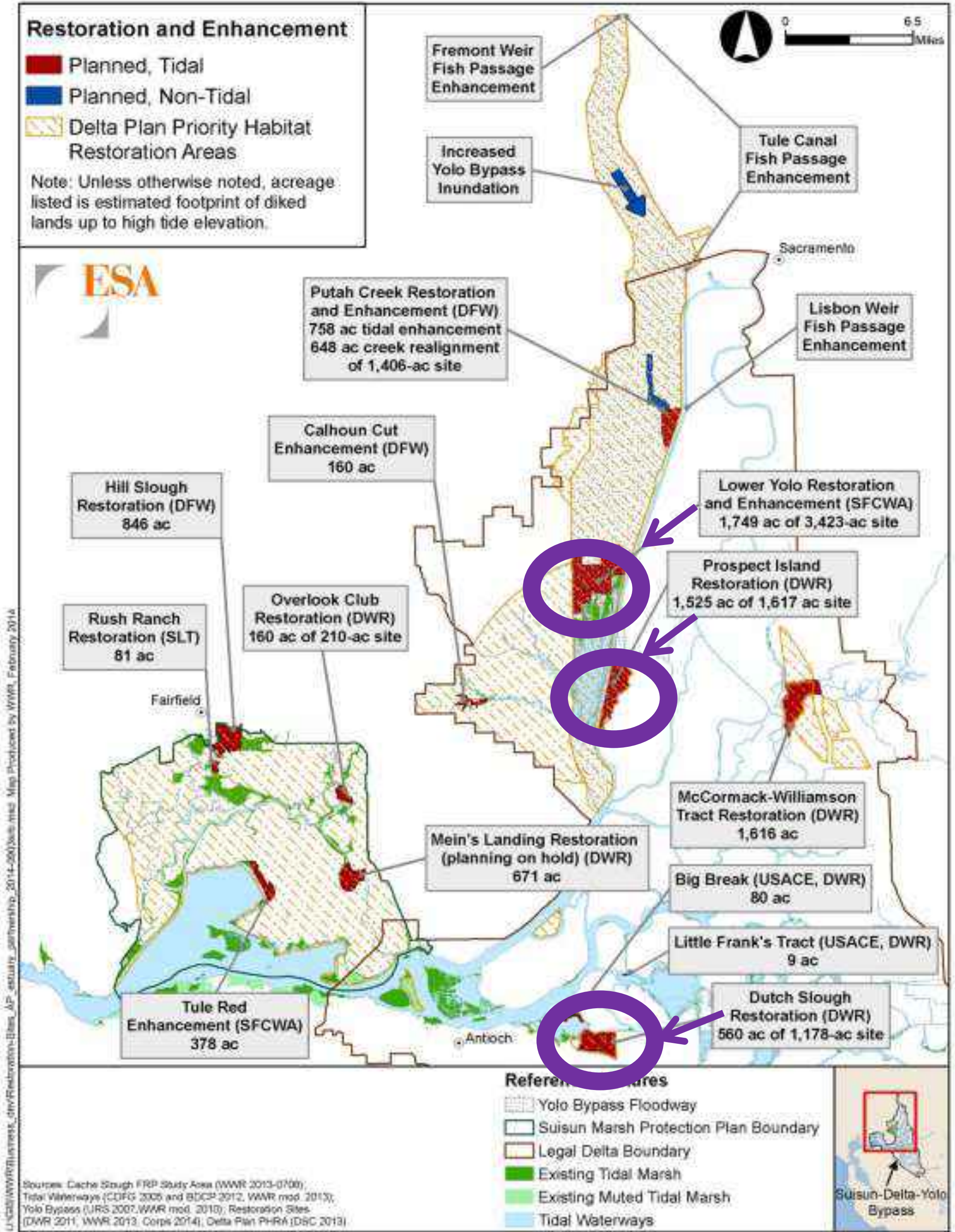
Resulting subsidy:

3% of existing copepod biomass d^{-1}



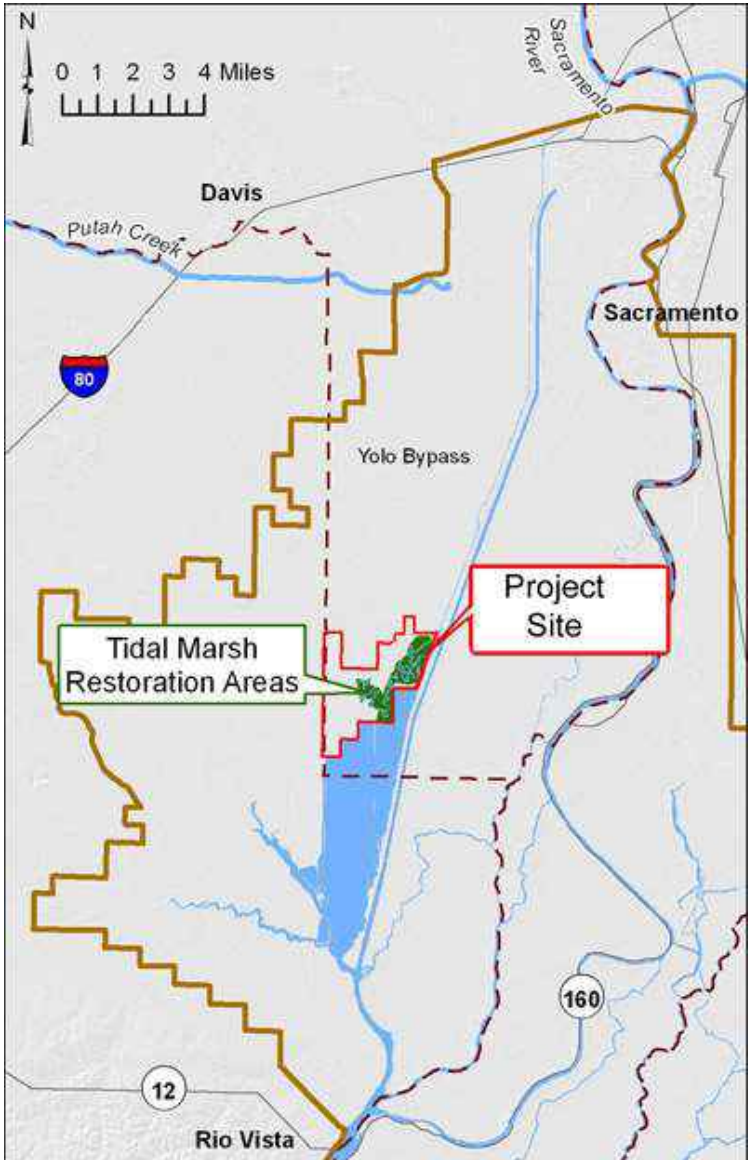
Depth and residence time control growth rates, grazing and biomass

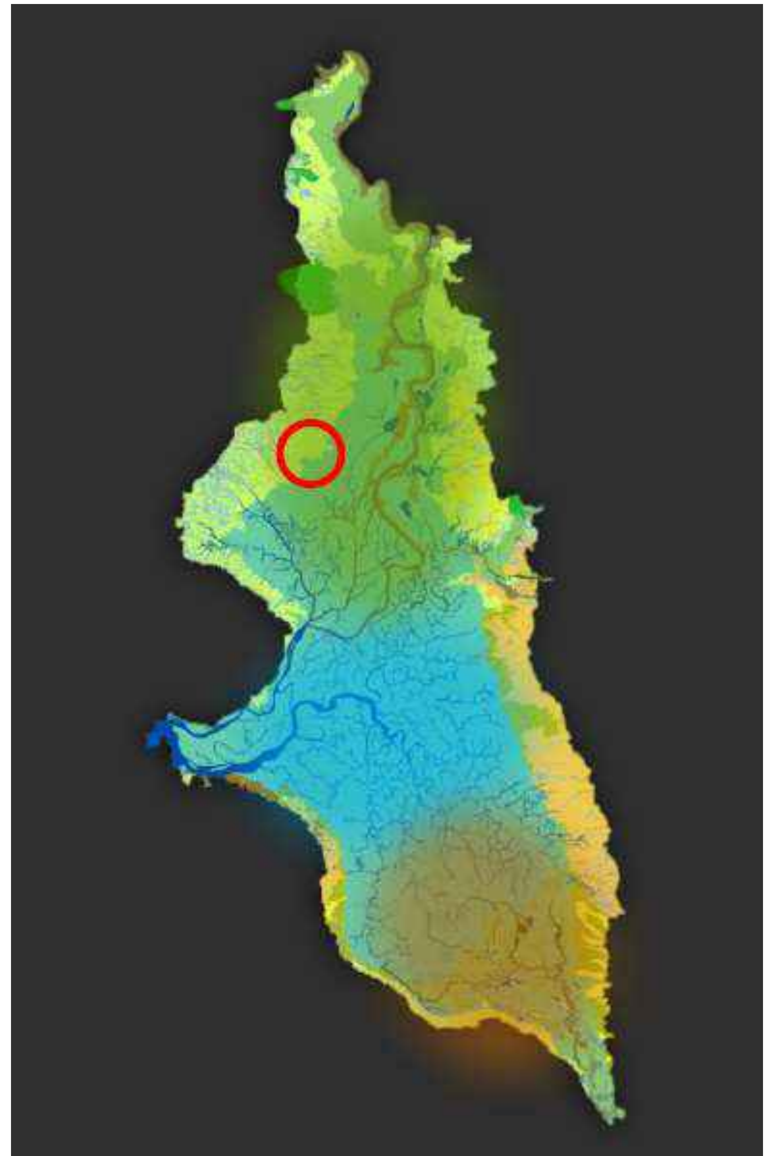
Thanks to Wim Kimmerer

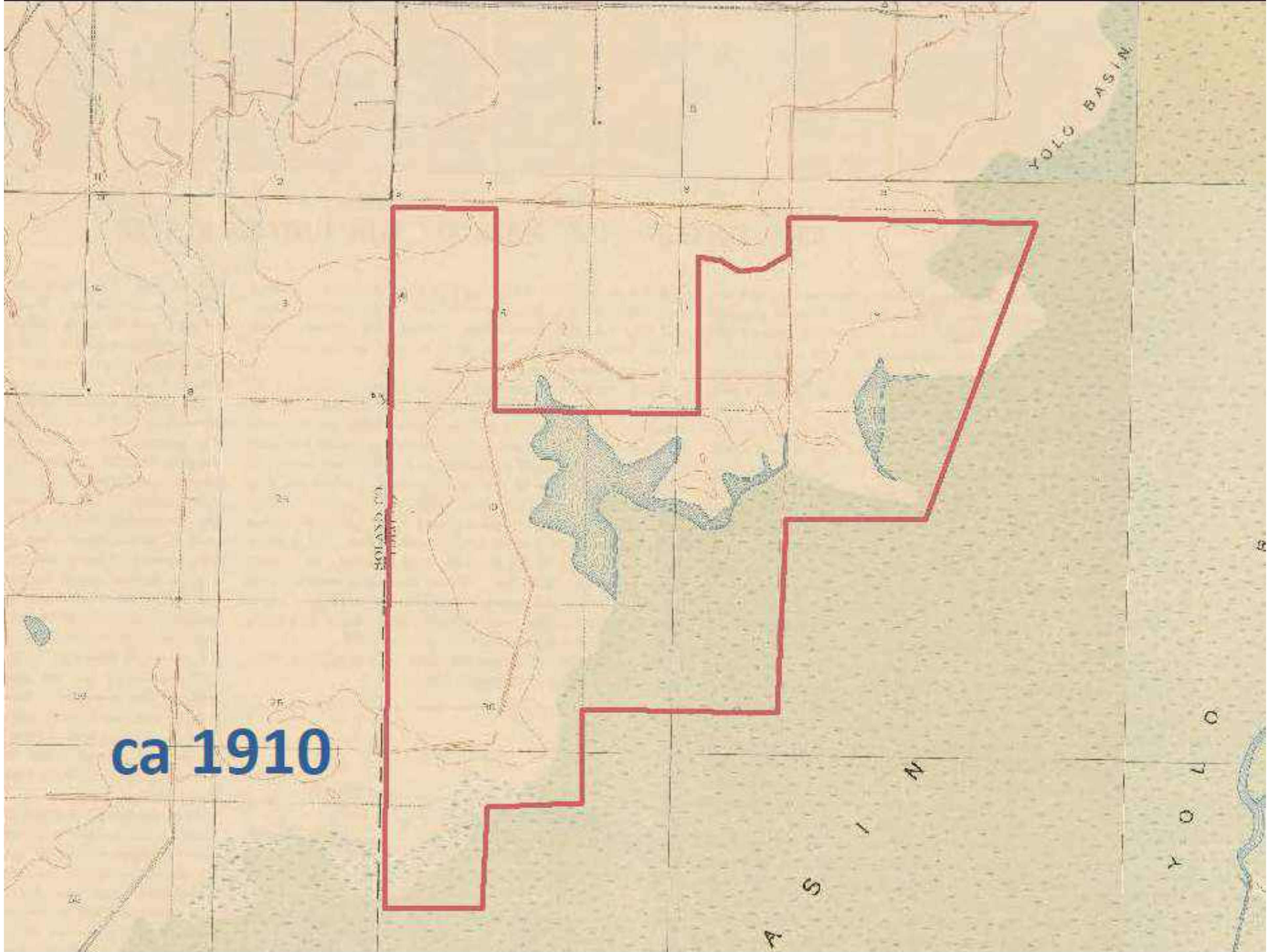


Restoration and Enhancement
Planned, Tidal
Planned, Non-Tidal
Delta Plan Priority Habitat Restoration Areas
Note: Unless otherwise noted, acreage listed is estimated footprint of diked lands up to high tide elevation.
ESA
0
6.5
Miles
Fremont Weir Fish Passage Enhancement
Increased Yolo Bypass Inundation
Tule Canal Fish Passage Enhancement
Sacramento
Putah Creek Restoration and Enhancement (DFW) 758 ac tidal enhancement 648 ac creek realignment of 1,406-ac site
Lisbon Weir Fish Passage Enhancement
Calhoun Cut Enhancement (DFW) 160 ac
Hill Slough Restoration (DFW) 846 ac
Lower Yolo Restoration and Enhancement (SFCWA) 1,749 ac of 3,423-ac site
Prospect Island Restoration (DWR) 1,525 ac of 1,617 ac site
Overlook Club Restoration (DWR) 160 ac of 210-ac site
Rush Ranch Restoration (SLT) 81 ac
Fairfield
McCormack-Williamson Tract Restoration (DWR) 1,616 ac
Mein's Landing Restoration (planning on hold) (DWR) 671 ac
Big Break (USACE, DWR) 80 ac
Little Frank's Tract (USACE, DWR) 9 ac
Tule Red Enhancement (SFCWA) 378 ac
Dutch Slough Restoration (DWR) 560 ac of 1,178-ac site
Antioch
Yolo Bypass Floodway
Suisun Marsh Protection Plan Boundary
Legal Delta Boundary
Existing Tidal Marsh
Existing Muted Tidal Marsh
Tidal Waterways
Suisun-Delta-Yolo Bypass
Sources: Cache Slough FRP Study Area (WWR 2013-0708); Tidal Waterways (CDFG 2005 and BDCP 2012, WWR mod. 2013); Yolo Bypass (URS 2007, WWR mod. 2010); Restoration Sites (DWR 2011, WWR 2013, Corps 2014); Delta Plan PHRA (DSC 2013)
Map Produced by WWR, February 2014

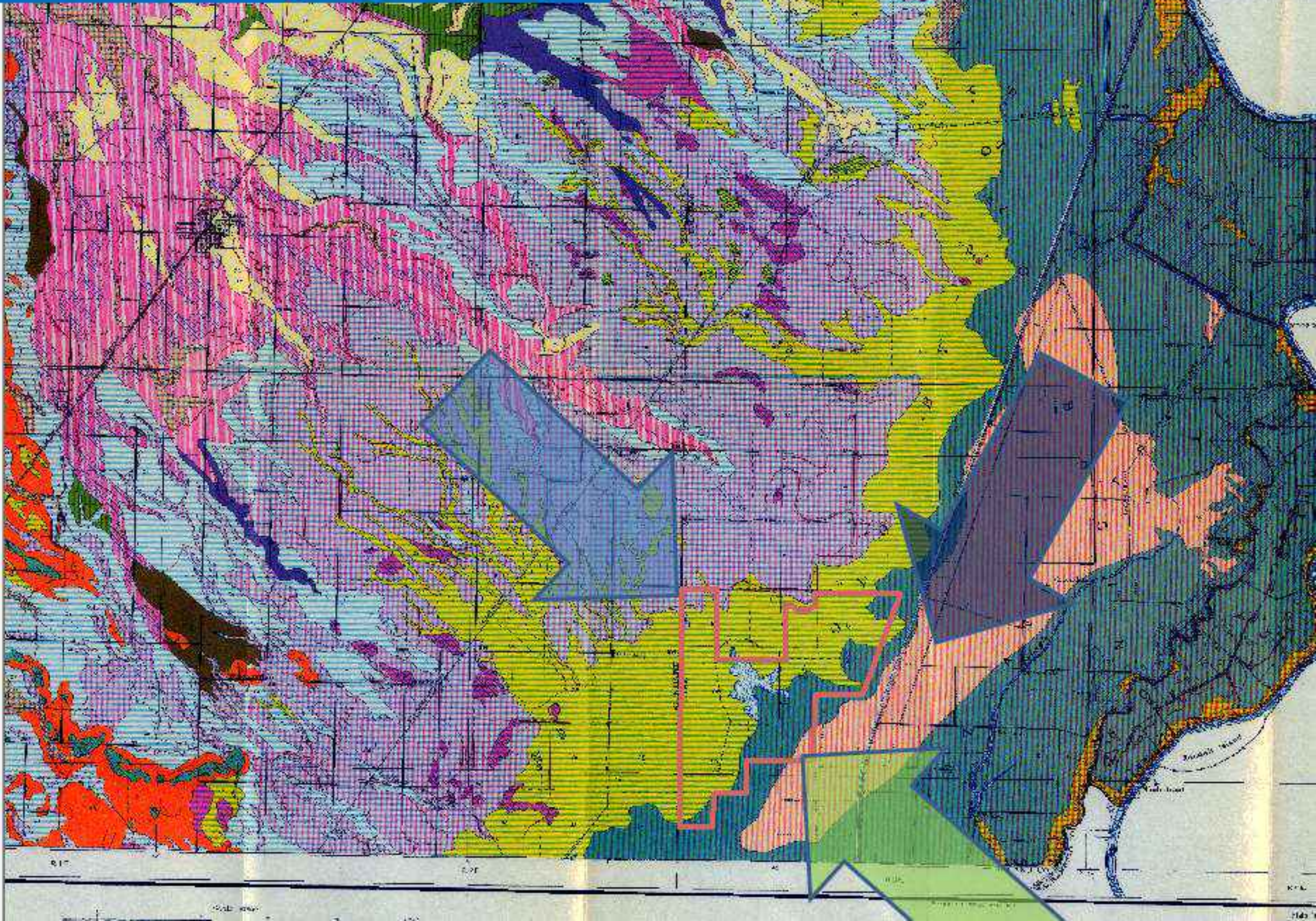
Lower Yolo Ranch



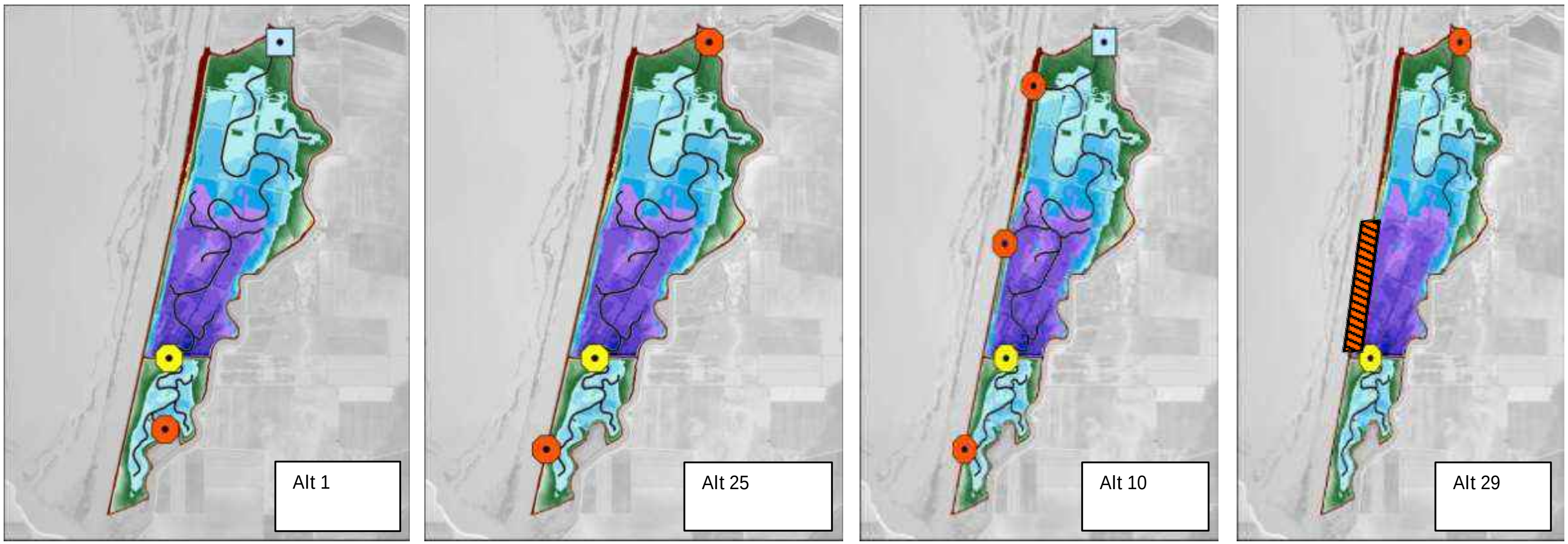



YOLO BASIN
BASIN
YOLO
ca 1910

Alluvial topography

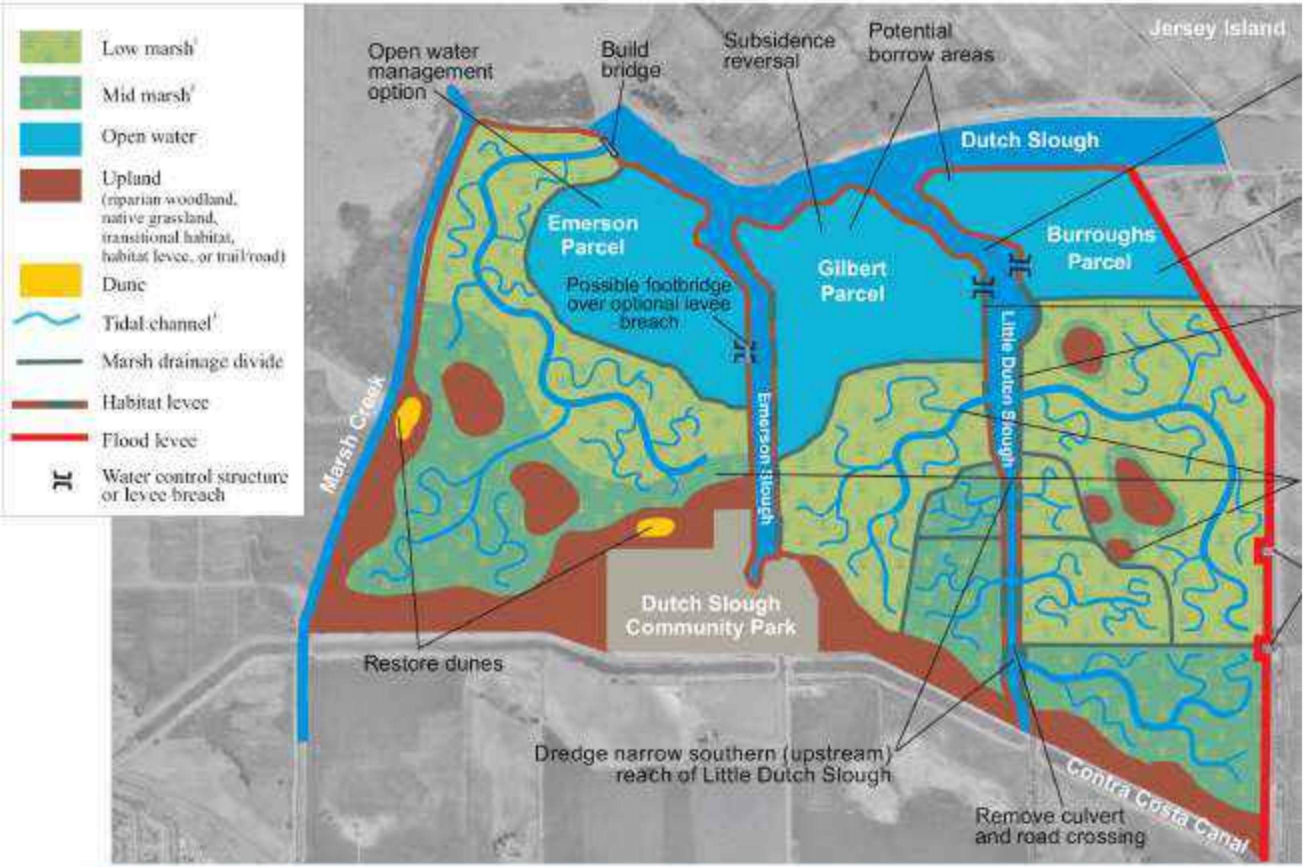


Prospect Island

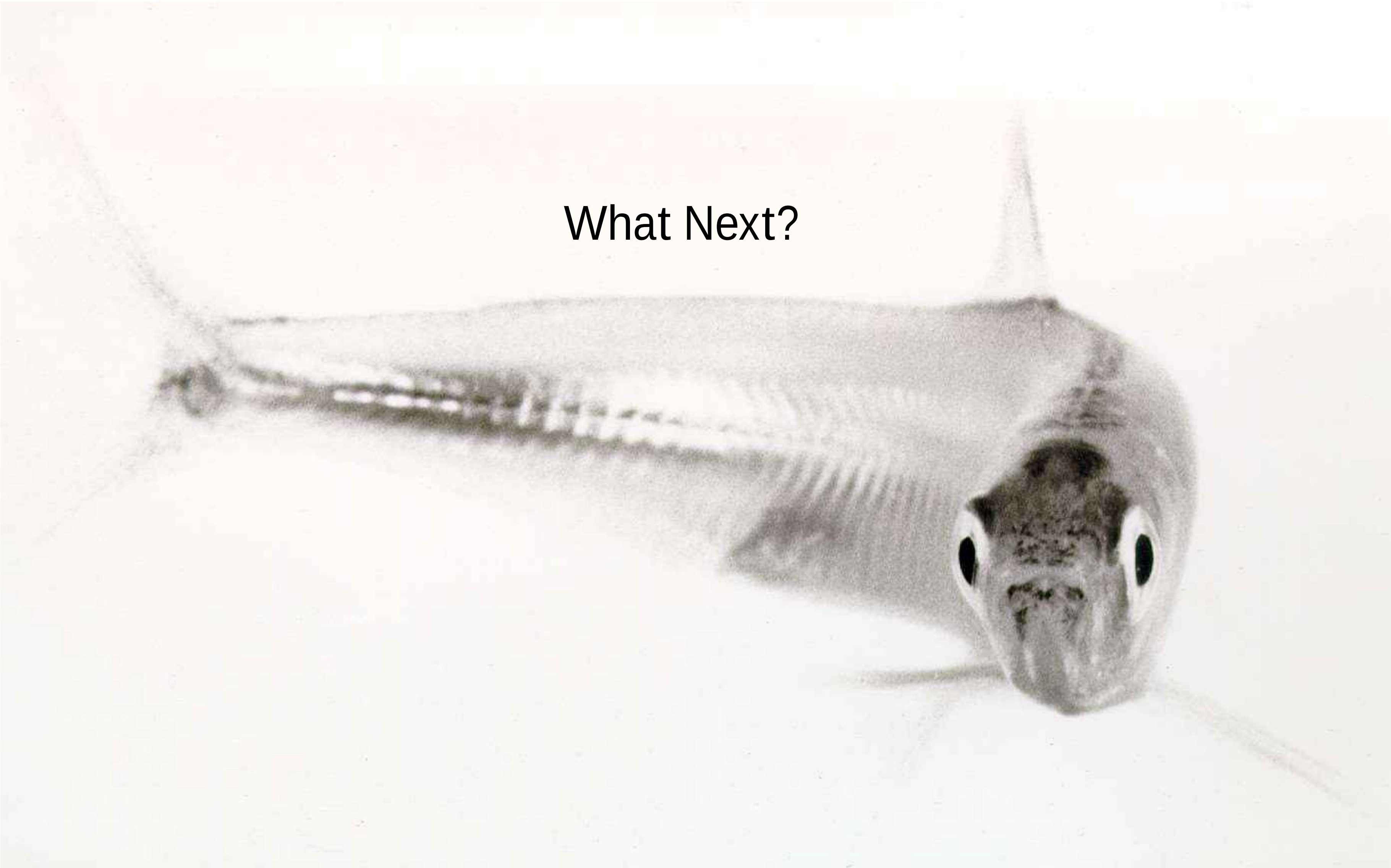


Thanks to Stuart Siegel, Carol Atkins and many other great folks on the Prospect Island project

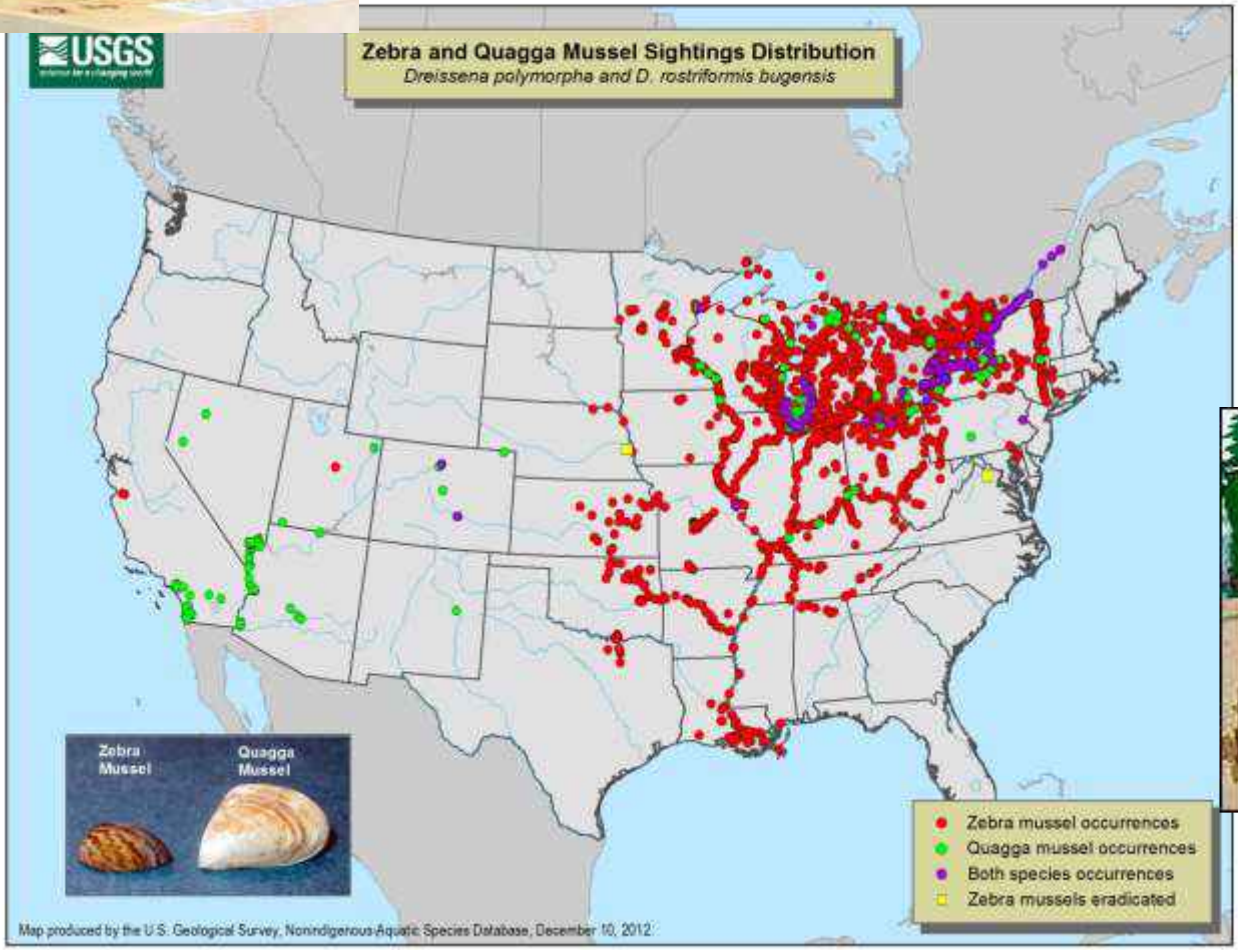
Dutch Slough



What Next?



Today?


Zebra and Quagga Mussel Sightings Distribution
Dreissena polymorpha and D. rostriformis bugensis
Zebra Mussel
Quagga Mussel
Zebra mussel occurrences
Quagga mussel occurrences
Both species occurrences
Zebra mussels eradicated
Map produced by the U.S. Geological Survey, Nonindigenous Aquatic Species Database, December 10, 2012

Earthquake or flood
64% chance in 50 years

1 M sea level rise in 100 years?